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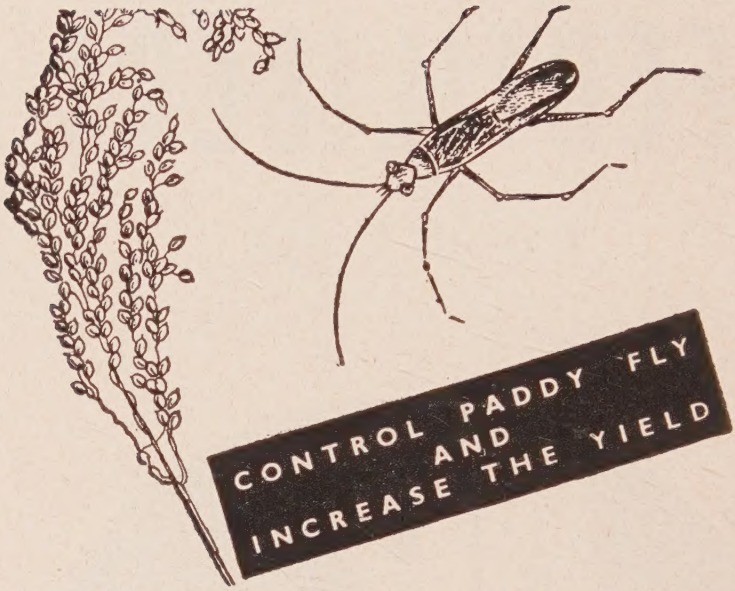

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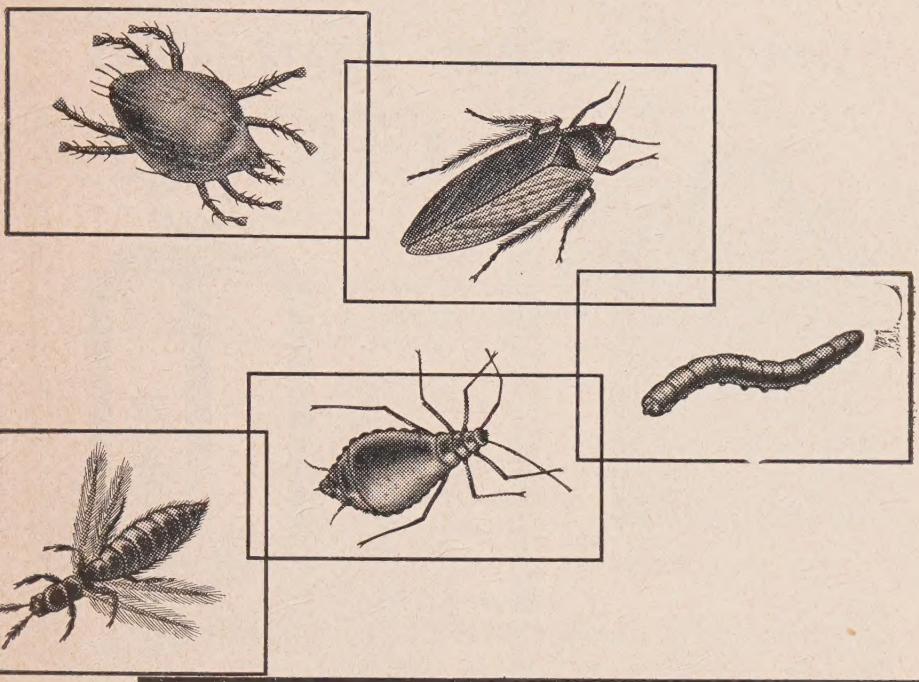

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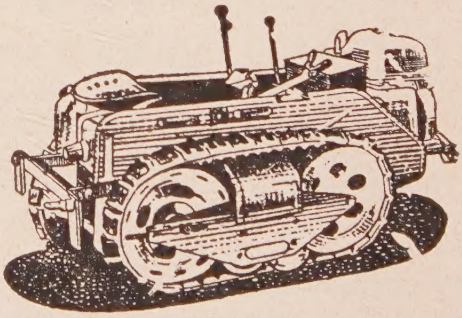

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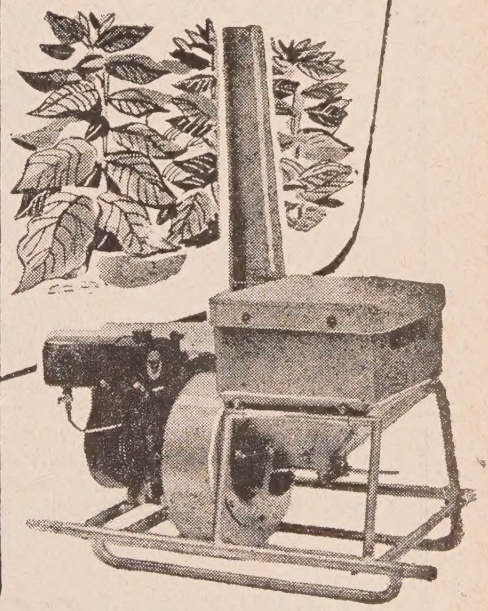

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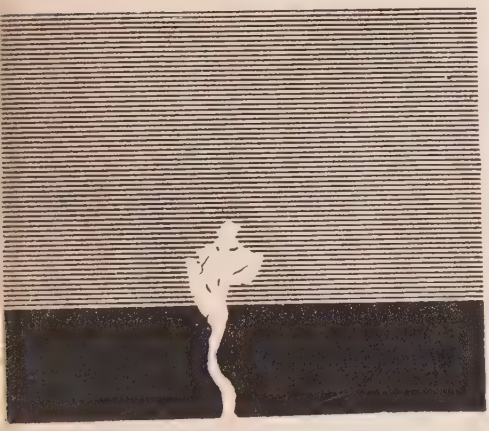

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VOLUME CXV, NUMBER 2, 1959

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DR. M. F. CHANDRARATNA
Director of Agriculture

CEYLON DEPARTMENT OF AGRICULTURE

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EDITORIAL

Policy for Poultry

ON the results of the Consumer Finance Survey, Ceylon's consumption of eggs in 1957 has been assessed at 126 million. Domestic production yielded 79 per cent of this quantity i.e., 100 million eggs. That the village hen provides over 90 per cent of these locally produced eggs is a fact of tremendous significance. This nondescript bird, whose virtues include resistance to disease and the capacity to forage, subsists almost purely on village waste. On the other hand, feed can account for 60—80 per cent of the costs of egg production with intensively managed pure-breds. The high egg-production costs that characterize the latter can be excused only if an adequate proportion of the feed utilized is locally grown. If there is a high degree of dependence on feed imports, it may be cheaper and more satisfactory to import eggs.

Recent advances in poultry development in this country reflect great credit on the Animal Husbandry Branch of the Department of Agriculture. With a view to achieving self-sufficiency in eggs, the incubator capacity in Government-owned hatcheries was expanded from 18,000 eggs per month in 1956-57 to over 143,000 in 1959-60. The rise of over 125,000 in hatching capacity should result in an annual increase of nearly 296,000 layers. If the total number of these layers consists of intensively managed, high-production breeds, domestic egg production should rise in a laying year by over 40 million.

The importance of extending artificial incubation to the free-foraging, village breeds has been persistently stressed by the Department's Animal Husbandry Branch. The striking success with which the Animal Husbandry Branch promoted the rearing of day-old chicks makes the rapid expansion of the population of village breeds possible. The provision of feed for these breeds, of course, presents no serious problems.

The most serious limiting factor to the expansion of poultry keeping on deep litter and other intensive systems is the difficulty of securing adequate supplies of cheap grain which, in rations recommended by the Department of Agriculture, compose 40 per cent of poultry feed. In 1957, Ceylon's maize acreage of 42,300 produced 358,100 bushels of grain. It is undoubtedly true that Government

should continue to promote the expansion of the maize acreage in this country, but even at present levels of production, there does not appear to be a serious shortage of grain for the intensively managed section of the poultry industry. The operation of the Guaranteed Price Scheme, however, makes maize an expensive grain. On the other hand, if the Guaranteed Price Scheme ceases to apply to maize, a marked shrinkage in the maize acreage would result. There appears to be no simple solution to the problem of securing cheap grain for use as poultry feed.

The most attractive feature of chick sexing is the opportunity it provides for economy of feed. The pace at which the training of personnel in chick sexing proceeds at present on Welisara Farm will permit the Department's hatcheries before the end of 1960, to ensure the complete sexing of their total annual out-put of nearly half a million day-olds.

Farmers, particularly the impecunious, find instability in prices for their produce most disturbing. Every year, egg prices register a depressing drop in the month of February. If Government's organization for the preservation of surplus eggs and for their carry-over into the lean months functions with high efficiency, these wild fluctuations in egg prices can be evened out.

Diseases, particularly Ranikhet, plagued poultry producers for many years. The control of Ranikhet has been one of the most impressive achievements of the Veterinary section of the Department of Agriculture in recent years. Not only is an effective vaccine being produced in adequate quantity in the Veterinary Laboratory—production of Ranikhet vaccine in 1958 amounted to 2,795,000 doses—but the routine maintained by the Department's team of over 100 vaccinators ensures that a very high percentage of the country's poultry receives vaccination before the age of three months. It is a matter for considerable gratification that Ranikhet has ceased to be a major hazard in egg production.

THE STATUS OF THE PADDY STEM BORER, *SCHOENOBIUS INCERTULAS* WALK, IN SOUTH EAST ASIA

By

P. MANICKAVASAGAR (Plant Protection Officer, Ceylon)

and

K. MIYASHITA (National Institute of Agricultural Sciences, Japan)

DISTRIBUTION

OF the insect pests of rice, the paddy stem borer, *Schoenobius incerticulas* Walk. has a wide distribution throughout the rice growing regions of South East Asia, and has been reported to be a menace to the rice crop in Afghanistan, Annam, Assam, Burma, Cambodia, Ceylon, China, Cochin, Formosa, India, Indonesia, Japan, Malaya, and the Philippines. The first systematic record of this pest was done by Moore in 1886 (17) and its nomenclature has gone through a series of changes thereafter. However, the presence of the insect in the rice fields of Formosa and Japan had been known to farmers, as far back as 1657 and 1777 respectively (22).

In 1917, Shiraki (22) presented a map showing the distribution of the paddy borer in the world. According to him, the distribution of this pest lies within the area from about 75° to 135° East longitude and about 10° South to about 35° North latitude, covering countries from India to Japan. As shown in Figure 1, the distribution range of the borer can be fixed at 70° East longitude, as the borer had been reported to affect rice in Afghanistan (5). On the northern hemisphere, the limit of distribution extends a little above 35° latitude in China (12) and slightly below 35° in the case of Japan. On the southern hemisphere, if not for the record of the borer moth being collected in Cassini island located on the northern coast of Australia, 125° East longitude by 15° South latitude (22), the limit of distribution might be Indonesia.

When we consider the distribution of this pest in relation to isothermal lines, the borer is chiefly distributed in the tropics. But in countries like China and Japan of the temperate zone, they are found specially in regions where the temperature in winter is constantly above 10°C, accompanied with an annual precipitation of 1,000 mm. or more. Table 1 gives the mean temperature and annual rainfall of weather stations in some of the countries where the pest occurs. The temperature and rainfall during the rice growing seasons for China, Japan, and Formosa have also been mentioned.

TABLE 1—Mean Temperature and Annual Precipitation

Countries	Weather Station	Mean Annual Temperature (C °)	Mean Annual Precipitation (mm.)
Burma	Rangoon	27·4	2312
Ceylon	Colombo	27·1	2492
China	Hongkong	22·3 (24·4)	2163 (2017 (Mar.–Nov.))
	Chungking	18·7 (23·9)	1054 (912 (April–Oct.))
	Shanghai	15·7 (21·9)	1133 (858 (April–Oct.))
Formosa	Dainan	23·1 (24·9)	1797 (1744 (Mar.–Nov.))
India	Benares	25·0	1031
	Calcutta	26·3	1610
	Madras	28·7	1118
Indochina	Saigon	27·5	2011
Japan	Fukuoka	15·1 (21·9)	1596 (1194 (May–Oct.))
	Kagoshima	16·6 (23·0)	2170 (1675 (May–Oct.))
	Kochi	15·6 (21·0)	2553 (2043 (April–Oct.))

Temperature and precipitation in parenthesis are for the rice growing period.

In China, the area in which the borer occurs, extends over the 10°C isotherm to approximately 0°C, where the annual precipitation is about 1,000 mm. at Shanghai, and 600 mm. at Tsingtau. Though Japan is also located on the 10°C isotherm, the borer distributes itself only in Kyushu, Shikoku and the south-western part of Honshu Island. Almost all the coastal regions included in the above-mentioned provinces face the Pacific Ocean, and have heavy precipitations in summer and less in winter, totalling about 1,200 mm. or more per year.

In order to explain the climatic limits of insect distribution, workers have presented different types of formulæ. Kinoshita and Yagi (13) calculated the—3.5°C line (minimum low temperature of average year) based on the relation between and temperature and death of overwintering larvæ, and concluded that the limit of distribution

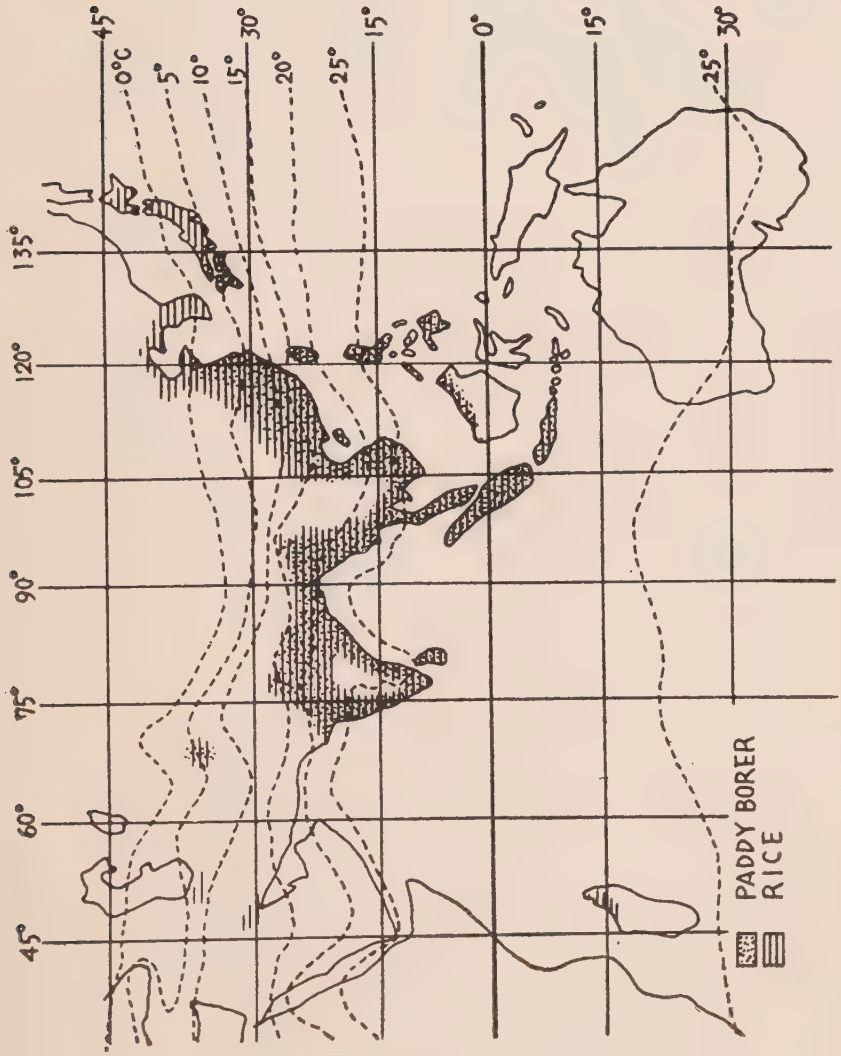

Fig 1.—Map showing the distribution of the paddy borer, and isothermal lines for the month of January.

coincided well with that line. This line approximately follows the 4°C line (Fig. 2). The detailed records maintained in respect of the distribution of the paddy borer in Japan, do not indicate it being prevalent in Tokai and Kanto areas, through which the 4°C isothermal line passes. Watanabe (cited in 15) presented the "20th March" line (the last date of water freezing) and Koyama (15) the—7.5 C° line. The lines calculated by these two workers too, do not tally entirely with the actual distribution in the field. Such lines, however give an idea of the close relationship between limit of distribution and temperature during winter.

LIFE HISTORY

THIS borer which belongs to the order Lepidoptera and is a larva of the Pyralid moth, has adapted itself to varying conditions of the tropical and temperate zones by aestivation, diapause and reduction in the number of generations according to conditions prevailing in each country. Table 2 gives the egg, larval, and pupal periods that the pest goes through in various parts of South East Asia. The egg and pupal periods in Japan are slightly longer than those of other countries, but there is hardly any difference in the periods in the phase of the pest's life cycle among the other countries mentioned.

TABLE 2—The egg, larval and pupal duration of S. incertulas in various countries

Countries	Egg period	Larval period	Pupal period	Reference
Ceylon	5–6	28–35	10–15	16
China	3–18 (11)	27–37 (32)	9–13 (11)	4
Formosa	6–7 (7)	24–35 (30)	4–11 (8)	22
India	5–6 (6)	28–35 (32)	about 10	21
	5–6 (6)	25–30 (28)	9–10 (10)	7
Indonesia	7–8 (8)	25–30 (28)	about 8	26
Japan	8–19 (14)	24–38 (31)	4–21 (13)	14
Malaya	5–7 (6)	about 35	8–12 (10)	20
Philippines	about 6	28–34 (31)	about 9	19

Figures in parenthesis indicate average duration of each stage.

Fig. 2.—The distribution of the paddy stem borer in Japan and the regions through which 4°C isothermal line (for January) runs.

On the other hand, the number of generations differ considerably from country to country (Table 3) with a tendency towards the decrease of generations in the northern limits of its distribution. In Japan and the north-eastern coastal regions of China the borer repeats only 2-3 generations, but has 4-8 in the south-eastern part of China, Philippines and Indonesia. In Japan, China (4), Philippines (25) and North India (8), the full-fed larvæ aestivate or hibernate during the dry seasons and in winter respectively. In southern Formosa, the borer has 6 generations, which somewhat overlap (Fig. 3) with no clear-cut aestivation or hibernation, while in Ceylon, Indonesia, India (south) and Malaya, aestivation has not been observed so far, and the borer seems to occur all the year round when rice is cultivated in rapid succession, thus causing an overlapping in the generations. The overlapping of generations is well illustrated by the number of egg masses deposited during each month, as observed by Corbett in Malaya (Fig. 4).

While dealing with the aspect of generations and the ability of the borer to control the number of generations, it would be of interest to make some observations on the types of generations that occur in Japan. Japan had, for the last five decades or so, maintained continuous light-trap records in respect of the important pests of the rice crop. The analysis of the light-trap records for *S. incertulas* shows that the type of seasonal moth emergence differs from place to place and year to year. The curves of moth emergence (Fig. 5) in 38 observatory stations distributed over the area in which the borer occurs can be divided into five distinct types according to the following characteristics :

1. Normal three generations type : the borer occurs three times normally having practically a uniform number in each generation.

2. Partial three generations type : the first and second generations occur normally, with some full-fed larvæ of the second going into hibernation. The rest of the second generation which forms a small group, passes on to the third generation.

3. Big first generation type : here the first two generations are normal but the third is partial. The moths in the first being more abundant than the other two.

4. Big third generation type : three generations occur normally, but moths are abundant in the third.

5. Four generations type : here four generations occur with few moths in the first generation and an equally high number in the third and fourth. This type was observed only in Kochi Prefecture, where rice is cultivated twice a year.

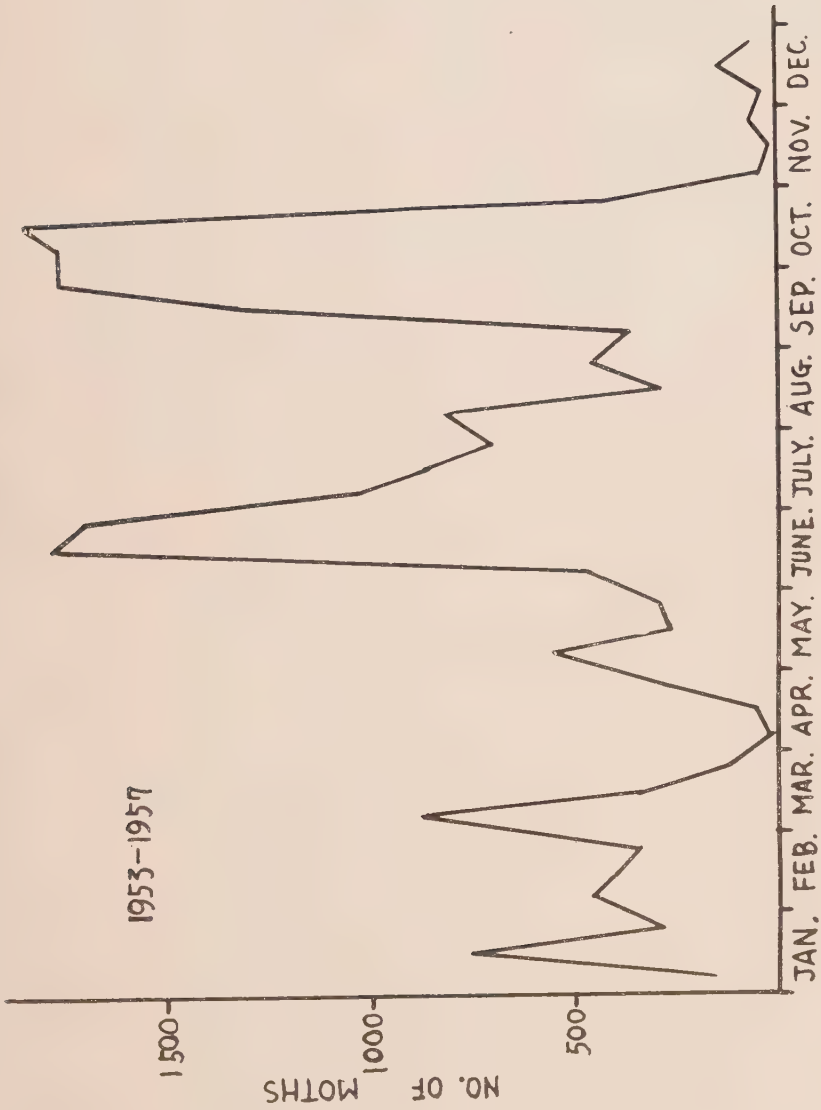

Fig. 3.—Curve indicating moth emergence in South Formosa. From the light trap records of Tainan Agricultural Experiment Station, Formosa. (Report of the Experiments and observations paddy pests, 1958. Mimographic copy.)

The difference in the types of moth emergence seems to be closely connected with climatic conditions and the system of rice cultivation practised in the locality. The cultivation of early varieties, and cool weather in late summer and autumn, are suspected to be important factors causing the partial three generations type. There is clear evidence that the borer can repeat 4 generations in Japan, when rice is cultivated twice a year.

DAMAGE AND CONDITIONS FAVOURING IT

THIS borer pest is considered to be the most destructive among the insect pests of the rice crop as it causes severe damage from seedling to maturity, season after season, specially in areas where rice is grown on an intensive scale and double cropping is practised. Very serious damage by this pest occurred in China in the years 1917, 1929, and 1935, resulting in heavy loss of yield. As is indicated in Table 3, the percentage of damage caused by this pest had been ranging from 0.1 per cent. to well over 80.0 per cent. during certain seasons, in heavily infested areas.

TABLE 3—Percentage of damage caused to rice crop by the paddy borer

Countries	Percentage of damage	Reference
Afghanistan	30	Cotterell (1954)
Ceylon	30	Leaflet 161 (1945)
China	0·2–70·0	Tsai Pang-Hwa (1935)
Formosa	0·5–50·0	Shiraki (1917)
India	2·8–87·5	Husain (1930)
Japan	0·1–39·8	Tsuboi & Noguchi (1955)
Malaya	28·9–62·3	Wyatt (1957)
Philippines	13·0–·30·0	Van der Goot (1948)

The paddy stem borer inflicts severe damage to the late crop in areas where double cropping is practised and damage increases with delayed planting (24). In Japan, the damage is less severe in areas where delayed planting is practised with single cropping. In such instances the vegetative growth of the rice seedling does not permit the large number of the first generation moths to rest and deposit their eggs.

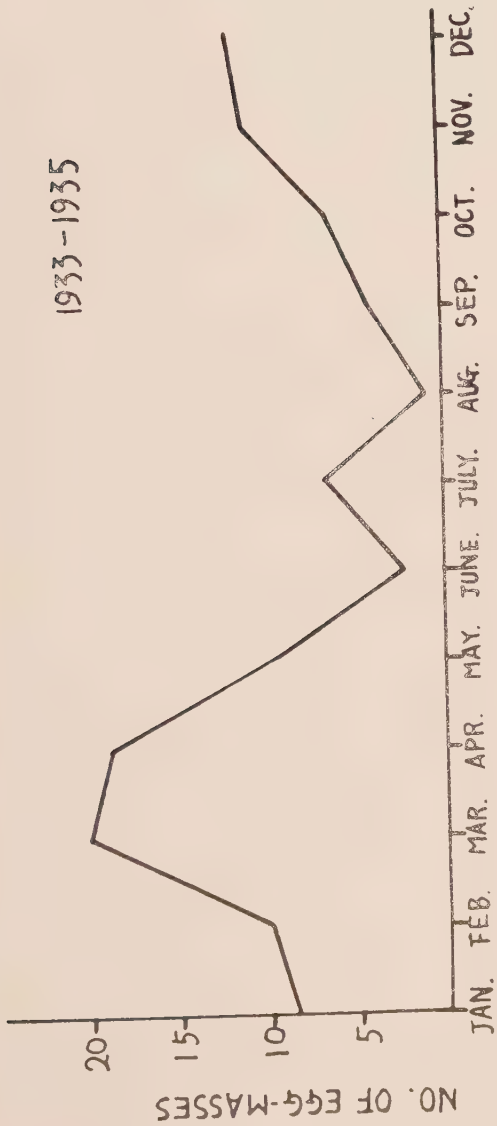

Fig. 4.—Monthly record of egg masses collected during the period 1933–1935 at the Agricultural Experimental Station, Krian, Malaya (6).

Since the moth requires a high relative humidity, it prefers low lying, swampy fields or fields where there is standing water for it to lay eggs (21, 24). Dense growth of the rice crop, and shaded conditions have also been reported to be conducive to the breeding of this pest. In India, the transplanted crop had been found to be more susceptible to borer infestation (21).

ALTERNATE HOST PLANTS

MANY workers have looked for alternate host plants of the paddy borer, but hardly any plants where the pest breeds to a fair extent have been recorded. Mention is made of wheat and some grasses in Burma (22) ; *Ischoemum striatum, Andropogon odoratus, Anthistiria ciliata,* (6) and *Oryza sativa* f. *spontanea* in India (1, 23) ; and some wild grasses in Ceylon (22). The haphazard system of mixing early and late maturing varieties and the continuous cultivation of rice afford a regular supply of food, spread evenly over a long period of time, year after year, for the moths to breed, and it is most probably due to this reason that the alternate host range had narrowed down.

CONTROL

DIFFERENT methods of control have been adopted in various countries in an effort to minimize the damage by this pest. Clean cultivation and maintenance of good depth of water in the fields have been stressed. In China, cutting the rice at ground level at harvest, reduced infestations in the ensuing season by 85 per cent (9). The burning of stubble has not proved very practicable.

The knowledge of this pest being phototropic has been utilised in Japan, where the traditional "Musi-Okuri" (Musi=insects ; Okuri=send away) festival was celebrated by farmers of the past, as far back as the 16th century (18). A similar festival known as "Karthikai theevam" (Karthikai=November ; Theevam=lights) had been in existence in India (21). These two festivals coincided with the shooting stage of the rice crop, and the lights of the festival served as light traps. A decade or two back, kerosene, petrol, and electric lamp traps were popular in China, India and Japan. The light trap was not effective against the paddy borer, but it was helpful in indicating the seasonal fluctuation of the pest. In Japan, light traps have indicated

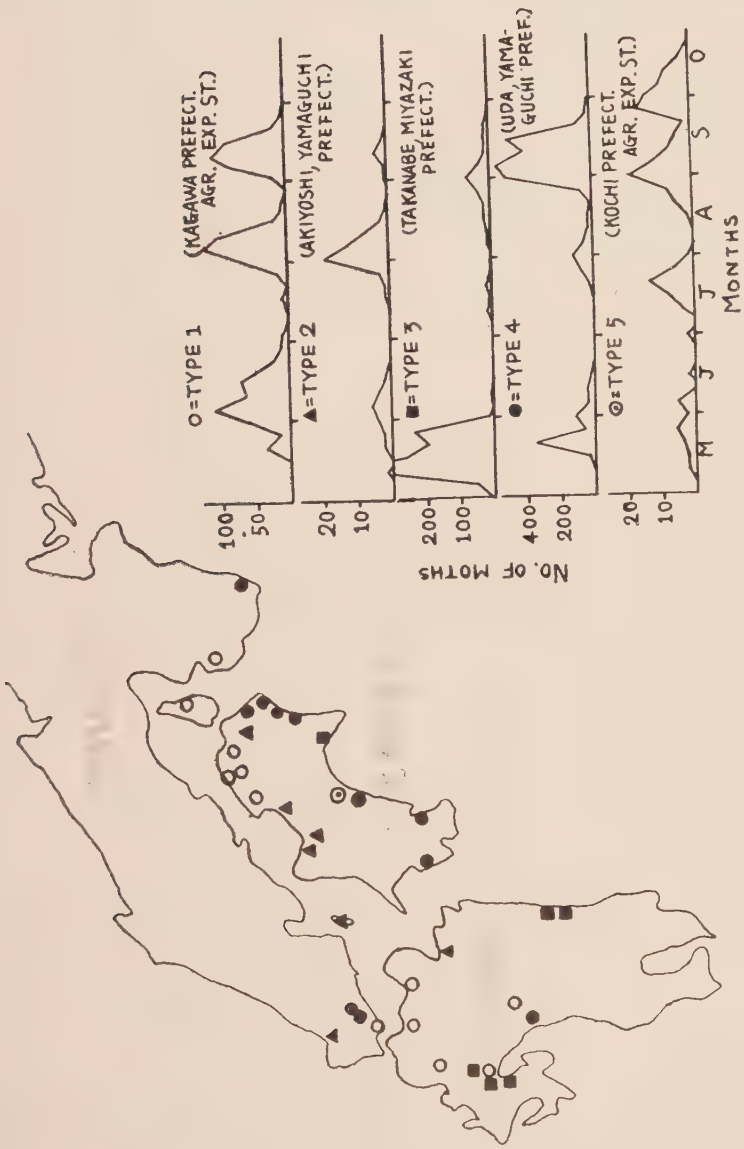

Fig. 5.—Five types of moth emergence curves and their distribution in Japan.

that the emergence of paddy borer moths ceases in the early part of June, and this knowledge has been utilised to delay planting of the rice crop in order to avoid infestation by this pest. The enforcement of delayed cultivation by the government had brought the pest under control in Japan within 2-4 seasons of cultivation as shown in Fig. 6.

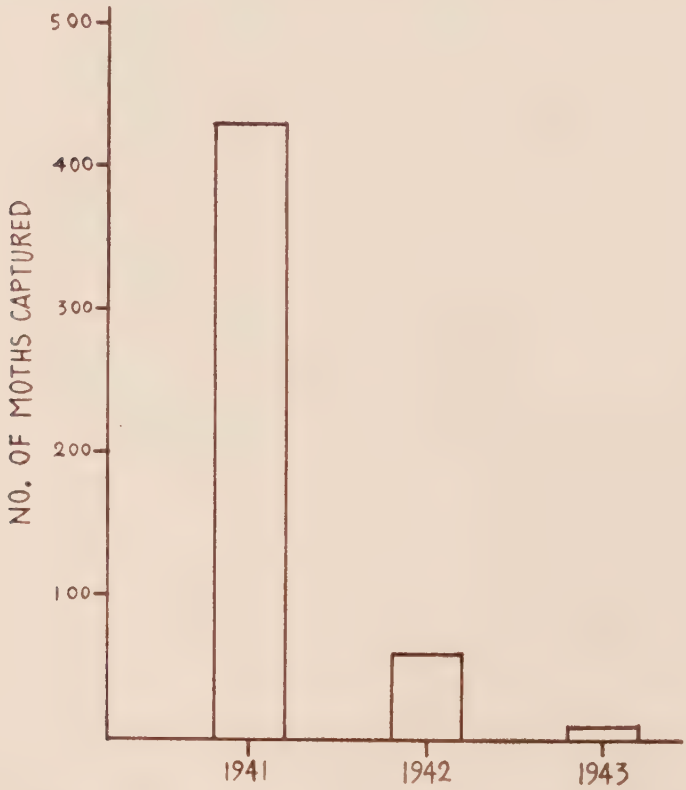

Fig. 6.—Indicating a fall in moth population in Kiragawa with the adoption of delayed planting in 1942.

With the advent of modern chlorinated hydrocarbons and organophosphorus insecticides, the borer menace has been reduced to a considerable extent. Parathion, DDT, and BHC were found effective in Japan. The application of DDT in nursery beds and the system of delayed planting proved effective in suppressing the occurrence of a second generation in Japan (11). In India and Ceylon, the use of endrin has given encouraging results. It is of interest to note that in India the use of endrin and parathion, not only controlled the pest, but also had stimulative action on the growth of paddy (23). Malaya recommends EPN and Dieldrin (28) and the Philippines, parathion (2).

In addition to the above-mentioned devices adopted by man, nature too has to a fair extent maintained a balance by way of parasites and predators. Table 4 gives a list of parasites that have been recorded in various countries (3, 10).

Resistant varieties : In India (21) well over a thousand varieties of paddy were tested for resistance against stemborer attack, but none proved to be free of borer infestation. Variation in the degree of infection was observed, but these variations were relatively inconsistant from year to year. In China 2,558 varieties were tested, but resistant varieties were not noted. However, there was a relation between the heading period and the degree of damage ; the varieties with late heading period showed light infestation (24). The reverse is true in Japan.

PROBABLE HOME OF THE BORER

THE conjecture that the original home of the paddy stem borer might be Ceylon (22) seems to be unfounded. It is clear that the prevalence of the borer follows the distribution of rice cultivation in South East Asia, and it appears likely that the original home of the pest was near the centre of origin of rice.

The paddy stem borer is monophagous and is entirely a pest of paddy, with hardly any alternate hosts of importance. Wild paddy and grasses have been mentioned as alternate hosts in the Madras and Andhra States of India ; wheat and grass have been mentioned in Burma.

The exact country or origin of rice is not yet known, but the weight of botanical-geographical evidence suggests that it originated in Asia (27). The centre of the origin of rice has been recently traced to areas around Orissa in India. Madras State, Andhra State and Burma extend in a belt along the Bay of Bengal with Orissa midway between Burma and the two states. Since Orissa and its neighbourhood have been suspected of being the origin of rice cultivation and as the switch-over of the pest from rice to other plants had been recorded round about this region, it is justifiable to assume that the original home of S. *incertulas* is in or round about Orissa. It must also be borne in mind that the stretch of land bordering the Bay of Bengal has an oceanic climate with high temperature, heavy precipitation and a relatively high humidity ideally suited for the prolific breeding of the borer.

3——J. N. B 18584 (11/59)

TABLE 4—Parasites of S. incertulas

Species	Countries									
	Ceylon	*China*	*Formosa*	*India*	*Indo-China*	*Japan*	*Java*	*Malaya*	*Philippines*	*Siam*
Egg parasites										
Eupteromalus sp. ..								×		
Gonatocerus sp. ..								×		
Habrocytes n. sp. ..							×			
Paederus idea Lewis ..		×	×			×				
Phidole noda Smith ..			×							
Telenomus beneficiens Zeh. ..		×	×	×		×	×			
Telenomus dignus Gahan ..		×							×	
Telenomus rowani Gahan ..			×	×	×		×		×	×
Tetrasticus schonenobii Fer. ..	×	×	×	×	×		×	×	×	×
Trichogramma japonicum Ashm.		×	×	×	×	×	×	×	×	×
Trichogramma minutum Riley ..				×						
Larval parasites										
Amauromorpha schoenobii Viereck			×							
Amauromorpha metathoracia Ash.		×					×		×	×
Angitia chilonis Cush. ..		×								
Aphiochoeta parastica Shiraki ..			×							
Apanteles ruficrus Haliday ..		×	×	×		×				
Apanteles schoenobii Wilk. ..				×						
Bracon chinensis Szep. ..		×	×			×			×	
Centeterus alternecoloratus Cush.		×								
Chelonus munkatae Munakata...		×				×				
Cremastus shiraki Sonan. ..		×	×							
Cremastus biguttulus Munakata		×	×			×				
Elasmus albopictus Cwfd. ..		×							×	
Eripter mus(?) akoensis Shiraki ..			×							
Eripternimorpha schonobil Vier..			×							
Euptermalus sp. ..		×								
Goryphus maculipennes Cam. ..				×						
Hormiopterus schoenobiroeus Rohwer							×			
Ischnojoppa luteator Feb. ..				×						
Lissonota japonica Matsumura ..						×				
Megaselia sp.		×								
Microbracon sp. ..		×								
Microplitis aonoriensis Mats. ..						×				
Rhaconotus oryzea Wilk . ..				×			×		×	
Shrakia doesalis Matsumura ..		×	×							
Stenobaacon trifasciatus Szep. ..		×	×			×	×		×	
Trathala (?) flavopedes Shiraki			×							
Tropobracon luteus Cam. var. indica R. A.				×						

SUMMARY

IN this paper an attempt had been made at a comparative study of the distribution, life cycle, alternate hosts, insect parasites and the extent of damage caused to rice by S. *incertulas*.

ACKNOWLEDGEMENT

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METHODS OF CALCULATING OPERATING COST OF AN AGRICULTURAL TRACTOR AND ITS EQUIPMENT

By S. B. GUPTA, Chief Engineer, and D. A. KUMARAGE, Chief Accountant
(*Department of Agriculture, Ceylon*)

IN arriving at an accurate evaluation of the cost of working an agricultural tractor and its ancillary equipment and in maintaining them in sound mechanical condition during the period of their working life, several factors have to be taken into account. In this article, an attempt is made to indicate the elements of cost that should be examined in such a computation.

All items of direct and indirect expenses that make up the operating cost of an agricultural tractor and its equipment are set out in the following pages.

For the purpose of this article only one item of operation has been considered, viz., disc ploughing by tractor. Any other operation may be treated in the manner discussed.

It has to be mentioned that, unlike in the case of a private individual who operates one or two tractors on hire, where a large organization maintains a fleet of tractors, there is bound to be substantial overhead expenditure involved in the general establishment but we have not attempted in this article to evaluate such overheads. They will vary with the size of the organization and, indeed, are not material to the discussion in this article as they are best treated under "management expenses" of the undertaking.

The authors also wish to state that in regard to certain items of expenses, e.g., indirect labour, indirect materials and lost time some generalization is made as it would be somewhat difficult to arrive at exact costs in such cases. But if it is remembered that costing can never be an exactly accurate computation under any circumstances, the data furnished will suffice to serve as an indication to those concerned with operating agricultural tractors of how the cost of running their machines is made up.

(A). TRACTOR.

The greatest single factor affecting the cost of operation of a tractor is the amount of hours of use per year. The total cost, on no loss no profit basis, is made up of two major items, viz :—

1. Fixed costs These include :

   (*a*) Depreciation and obsolescence.

   (*b*) Interest on investment.

   (*c*) Housing.

   (*d*) Taxes.

   (*e*) Insurance.

2. Running costs. These include :

   (*a*) Direct labour.

   (*b*) Indirect labour.

   (*c*) Direct materials.

   (*d*) Indirect materials.

   (*e*) Lost time.

   (*f*) Repair costs.

(B). EQUIPMENT.

In the case of equipment the total operating cost is made up of :

(*a*) Depreciation.

(*b*) Interest on investment.

(*c*) Housing

(*d*) Taxes.

(*e*) Insurance.

(*f*) Repair cost.

(A) TRACTOR

Description	Cost per Hour	Example
1. (a) Depreciation and obsolescene. Depreciation is the loss in capital value and service capacity of the tractor through use, natural wear and tear, physical decay, rust, corrosion and accidental damage. The total service life of a tractor must be known or assumed in order to determine depreciation. It is not possible to wait until a machine is worn out to determine how long it should last. Out of the three most useful methods, i.e., "Straight-Line" method, "Reducing-balance" or "Constant-ratio" method, and the "Sinking fund" method, the first one is the simplest for calculating the depreciation of this type of plant. Obsolescence is the reduction in value of the existing machine, due to the machine becoming old fashioned and out moded. There is continuous progress in the development of better machines. Obsolescence may lead to plant being replaced while it is still capable of production. Though it still has physical life, its economic life is at an end.	Purchase price of the Tractor—Estimated salvage value of the tractor at the end of its total service life ——— Total service life of the tractor in hours.	Suppose : The purchase price of the Tractor is Rs. 10,000. (ii) The estimated salvage value of the tractor at the end of its total service life is Rs. 200 (iii) And the total service life of the Tractor is 10,000 hours Then the depreciation will be :— $= \frac{\text{Rs. } 10{,}000 - \text{Rs. } 200}{10{,}000 \text{ hours}}$ $= \frac{\text{Rs. } 9800}{10000}$ or Rs. 0.98 per hour

Description	Cost per Hour	Example
1. (*b*) Interest on investment. This is a fixed item i.e., it is independent of annual use. The amount invested in a tractor is greater during its early life than during the later years, since an amount is written off each year for depreciation. Interest charges are desired when operating costs are being determined but not when depreciated values are being determined for resale. It is desirable to calculate interest charges by a method that results in constant or equal yearly charges throughout the machine's life, where operating costs are concerned. The sum of the interest charge and the depreciation should be constant. The rate of interest itself is affected by the amount of risk involved. For Farm Machinery it varies from 3 to 6 per cent. per annum.	$\frac{\text{Annual interest charge} \times \text{total service life of the tractor in years}}{\text{Total service life of the tractor in hours}}$ $\text{(Annual interest charge} = \frac{\text{Tractor purchase price} + \text{Estimated salvage value of the tractor}}{2} \times \text{rate of interest}$	Suppose the total service of the Tractor is 10 years and the rate of interest in this case is 5 per cent., then the interest on investment will be :— $= \frac{10{,}000 + 200}{2} \times \frac{5}{100} \times \frac{10}{10{,}000}$ $= \frac{51}{200}$ or Rs. 0·25 per hour
1. (*c*), 1. (*d*) and 1. (*e*) Housing, Taxes and Insurance. Annual charges for housing, taxes and insurance may usually be determined best by considering the specific case. If better estimates are not available, the following charges may be used as typical for Farm Machines in general : Housing 1·60 per cent., Taxes 2 per cent. and Insurance 0·40 per cent. per annum	$\frac{\text{Annual charges} \times \text{total service life of the Tractor in years}}{\text{Total service life of the Tractor in hours}}$ $\text{(Annual charges} = \frac{\text{Tractor purchase price} + \text{Estimated salvage value of the Tractor}}{2} \times \frac{\text{Sum of rates}}{100}$	Taking the same rates as given in the description, then these charges will be :— $= \frac{10{,}200}{2} \times \frac{1{\cdot}60 + 2 + 0{\cdot}40}{100} \times \frac{10}{10{,}000}$ $= \frac{51}{250}$ or Rs. 0·20 per hour

2. (*a*) Direct Labour. The wages, salaries and allowances of the operator directly engaged to operate the tractor	$\frac{\text{Total annual emoluments of the operator}}{\text{operating hours per year}}$	Suppose the total annual emoluments of the operator is Rs. 2,700, and the operating hours per year are 1,000 then the direct labour charges will be :— $= \frac{2,700}{1,000}$ or Rs. 2.70 per hour
2. (*b*) Indirect Labour. This includes the cost of the staff engaged in the supervision and management of the machine. It varies from department to department, organisation to organisation and depends upon the number of tractors a department or organisation has to work and look after. Further it depends upon the size of the area within which a given number of tractors are required to be worked and supervised. In a small area it may be possible to manage and supervise the work of a given number of tractors with less supervisory staff than it would be necessary with the same number of tractors in a larger or scattered area. In this case more staff is needed to ensure efficient supervision of field operations. It is directly proportional to the direct labour. But in general it may be taken as 25 per cent. of the direct labour-	25 per cent. of the direct labour charges per hour	$= \frac{25}{100} \times \frac{270}{100}$ $= \frac{27}{40}$ or Rs. 0·67 per hour
2. (*c*) Direct materials. Costs of fuel and lubricating oils. It is the largest single item of expense in operating a tractor.	(i) Consumption of fuel :— Average consumption of fuel per hour in gallons × cost of one gallon of fuel	Assuming the average consumption of fuel (diesel) of the tractor per hour is 1·5 gallons and cost of one gallon of fuel is Re. 1·20 then :— $= \frac{3}{2} \times \frac{120}{100}$ $= \frac{9}{5}$ or Re. 1·80 per hour

Description	Cost per Hour	Example
	(ii) Consumption of Engine Oil :— Air Cleaner capacity in gallons / Engine Sump capacity in gallons / Compensating oil for topping up in gallons ——— × ——— × ——— Frequency of change in hours / Frequency of change in hours / No. of hours in which topping is done × Cost of one gallon of oil	Suppose the Air Cleaner capacity is $\frac{1}{8}$ gallon and its frequency of change is after every 10 hours, engine sump capacity is $1\frac{1}{2}$ gallons and its frequency of change is after every 120 hours, and after every 10 hours working 1/20 gallon is needed for topping up, then :— $= \frac{1}{8} \times \frac{1}{10} + \frac{3}{2} \times \frac{1}{120} + \frac{1}{20} \times \frac{1}{10}$ $\frac{3}{100}$ Gallon per hour $= \frac{3}{100} \times$ Cost of one gallon of engine oil (say Rs. 8) $= \frac{3}{100} \times \frac{8}{1}$ $= \frac{6}{25}$ or Rs. 0·24 per hour
	(iii) Consumption of gear oil :— Capacity of gear box, differential and hydraulic system, &c., in gallons ——— +	Suppose the capacity is 6·5 gallons and the frequency of change is after every 60 hours working 1/16 gallon is needed for topping up then :—

	Frequency of change in hours / Compensating oil for topping up in gallons	$= \frac{13}{2} \times \frac{1}{720} + \frac{1}{16} \times \frac{1}{60}$
2. (*d*) Indirect Materials. Cost of materials such as flushing oil, cotton waste, grease, radiator cleaners, and other rust removing and washing materials used in the upkeep of the tractor. In general it may be taken as 10 per cent. of the direct materials.	No. of hours in which topping is done × Cost of one gallon of gear oil / 10 per cent. of the direct material charges per hour.	$= \frac{29}{2280}$ Gallon per hour
2. (*e*) Lost time. It is the most difficult variable to evaluate in relation to field capacity. Field time may be lost in adjusting or lubricating machine, adding fuel, minor breakdowns, clogging and idle travel such as travelling to field and turning at ends &c. Loss of time affects directly on the direct labour and direct material and in any case it should not exceed more than 20 per cent. of these charges.	20 per cent. of the direct labour and direct material charges per hour	$= \frac{29}{2280} \times$ Cost of one gallon of gear oil (say Rs. 10) / $= \frac{29}{228}$ or Rs. 0·10 per hour
2. (*f*) Repair cost. The total repair cost to maintain a tractor during its full service life includes the cost of the tools and appliances, spare parts, wages, salaries and allowances of the mechanics and other staff engaged in the overhaul of the machine, the cost of transport in taking the tractor to the workshops for repairs and back to its work site after repairs, and the transport charges of the staff sent out to attend to field repairs, &c. The total repair cost, as given in the A. S. A. E. 1959 edition year book is, for a tractor, 120 per cent. of the new cost with 12,000 hours to wear out and 15 years until	100 per cent. of the purchase price of Tractor / Total service life of Tractor in hours	$= \frac{10}{100} \times \frac{214}{100}$ / $= \frac{107}{500}$ or Rs. 0·21 per hour / $= \frac{(20)}{100} \times (2{\cdot}70 + 2{\cdot}14)$

Description	Cost of Hour	Example
obsolete. In this case it may be taken as 100 per cent. of the purchase price with 10,000 hours (to wear out) as its total service life in hours and 10 years (until obsolete) total service life in years.		$\frac{121}{125}$ or Rs. 0·96 per hour $= \frac{100 \times \text{Rs. } 10{,}000}{100 \times 10{,}000 \text{ hours}}$ = 1 or Rs. 1.00 per hour
	TOTAL OPERATING COST OF THE TRACTOR PER HOUR (Sum of 1 and 2)	Rs. 9·11
(*a*) Depreciation	Estimated purchase price of the equipment—salvage value Total service life of the equipment in hours	Suppose: The equipment is a 3/Furrow disc plough and its purchase price is Rs. 2,220 (ii) Its estimated salvage value is Rs. 50 (iii) And its total service life is 2,000 hours Then the depreciation will be :— $\frac{2220 - 50}{2000}$ $= \frac{217}{200}$ or Rs. 1·08 per hour
(*b*) Interest on investment, Housing, Taxes, and Insurance. 9 per cent. per annum.	Annual charges × Total service life of the equipment in years Total service life of the equipment in hours	$\frac{2220 + 50}{2} \times \frac{9}{100} \times \frac{10}{2000}$

		$= \frac{2043}{4000}$ or Rs. 0.51 per hour
(c) Repair cost. Total repair cost 30 per cent. of the purchase price of the equipment	30 per cent. of the purchase price of the equipment / Total service life of the equipment in hours.	$\frac{30}{100} \times \frac{2220}{2000}$ $= \frac{333}{1000}$ or Rs. 0.33 per hour

TOTAL OPERATING COST OF THE EQUIPMENT PER HOUR SUM OF B. (*a*), B. (*b*) and B. (*c*) Rs. 1.92

GRAND TOTAL OF OPERATING COSTS OF THE TRACTOR AND THE EQUIPMENT PER HOUR (SUM OF A AND B) Rs. 11.03

COST OF DISC PLOUGHING PER ACRE (WITHOUT PROFITS)

= Operating cost of the tractor and equipment per hour × hours required to plough and Acre

= Rs. 11·03 × 2·3 hours (assuming 2·3 hours are required to do one acre)

= Rs. 25·37 per acre.

MECHANICAL DEVICES FOR ROW-SEEDING SWAMP RICE

By S. THAMBIYAH
Secretary,
Agricultural Implement Testing Committee, Department of Agriculture, Ceylon

THIS communication presents a report of the progress achieved by the Agricultural Implement Testing Committee in the Development of Mechanical Devices for row seeding swamp rice.

The traditional practice of cultivating rice under swamp conditions in Ceylon involved ploughing, puddling, levelling and draining the field before broadcasting sprouted seed. Under conditions of broadcasting effective weed control is rarely achieved. The broadcast crop is often hand weeded at high cost but the increased yields obtained are not sufficient to compensate for the extra expenditure involved. " Harrowing of the standing crop " was advocated by the Department as a simple and cheap method of obtaining better yields from broadcast crops. Although this operation is beneficial, nevertheless, it has not found favour with the cultivators presumably due to the reluctance to allow buffaloes to tread the crop. Besides in seasons and areas where water is short it is not possible to " harrow the standing crop " at the optimum stage whereby the crop often suffered.

The normal practice adopted by cultivators to control weed is by keeping the fields flooded, thereby submerging the weed. Deep irrigation through advantageous in controlling weed to a limit causes severe lodging and yield and seed quality are lowered. Besides, in a country where constant crop failures are attributed to water shortage at the crucial periods in the growth of the crop, such extravagant use of water is not a practice that can be encouraged.

In this instance it may be necessary to mention that dry sowing (*kekulan*) has been practised in limited areas in the country. On large farms, seeding with animal and tractor drawn drills has been

tried. Though efficient drills are available for seeding under dry conditions, factors such as properties of the soil, size of bays, uncertainty of monsoonal rains for timely preparations of the land and the water for irrigation at the proper time limit this practice. Besides, most farmers who depend on hand and animal-drawn implements for preparatory tillage are unable to prepare level seed beds of good tilth in most areas.

Even with careful preparatory tillage, weed control on the broadcast extent of nearly 1,160,000 acres representing over 90 per cent. of the Island's rice acreage is relatively inefficient. Transplanting rice as an alternative to broadcasting was advocated for about the last two decades. Although this practice has many advantages besides water economy and increased yields, various factors including shortage of labour and excess or insufficiency of water permit the adoption of transplanting only on a small fraction of Ceylon's rice acreage.

In a report submitted to Government three officers who had undergone a training in rice cultivation in 1954 in Japan mentioned that, " Row cropping is really the ' hub ' of all field practices that contribute to high yields. Every single acre is row cropped and it is considered a ' must ' in rice cultivation. In order to obtain the best performance of each plant, uniform stand of crop, efficient weed control, intercultivation and even distribution of nutrients in the soil are essential ; and this is possible only under row cropping. They recommended that, " In areas where transplanting is already an established practice, attempts may be made to introduce row planting. The method of broadcast sowing has to be changed on to drilling or dibbling, or transplanting in rows. So far no satisfactory seeders have been designed as direct sowing is not common. Hence an efficient seeder for wetland conditions has to be designed early. "

Between '55 and '56 a number of observations and trial plots were laid in various Departmental stations and Farmers' holdings to test out the performance of row seeding. In these trials make-shift arrangements and hand-seeding was resorted to. It was convincing from these observations that row seeding followed by inter-cultivation with the Japanese rotary weeder provided completely satisfactory weed control besides all other advantages of row cropping. In Departmental trials, yields from row seeded plots have often been higher than under conditions of transplanting.

Under these conditions the necessity for suitable mechanical aids for row seeding of swamp rice was created. A number of Departmental Officers and others produced designs which are described briefly below :—

SEEDER No. 1 (DE SOYSA)

This is a modification of the Indian highland seed drill. From the seed bowl four light G. I. sheet tubes lead to a light head piece. The head piece is supported on the soil by two boat-shaped floats whereby the ends of the tubes are held about three inches from the soil surface. The handle for drawing the Implement emanates from the head piece. The Implement is operated by two persons—One draws the implement while the other follows to feed the seed through the seed bowl. The seed regulation depends on both operators. Mention is made of this since it may have influenced the development of some seeders described herein.

SEEDER No. 2 (JOHNPULLE)

The seeder consists of a rectangular sheet-metal seed box open at the top. On the floor of the box along the seed delivery compartment are a row of six holes 3/4 in. in diameter from which six tubes lead down to a light head piece. The ends of the tubes are fixed eight inches apart and so as to be 3 in. from the soil surface in the operating position. The frame connecting the head piece to the seed box provides rigidness to the whole implement. Small pegs fixed on the head piece behind each tube serve to open gentle furrows along which the seed is deposited. Guide brackets are fixed at both ends and help in following the seeded laps.

The seed box is provided with three plates with different size perforations to alter seed rate. A partition originating above 1/4 ins. from the floor of the box divides the box into seed container and seed delivery compartments. The implement is dragged backwards while with one hand the seed in the delivery compartment is agitated. The seed passes through the perforations in the plate, runs down the tubes and is deposited along the furrows. The efficiency of seeding is controlled by the speed of the operator and manner of agitation. With practice the operator could develop a certain degree of skill to effect uniform seed drop.

SEED No. 3 (SIMEON)

THIS is essentially similar to number 2 but an attempt was made to eliminate hand agitation of the seed. The box is modified to take a wooden grooved roller with a pulley at one end. The head piece also carries a roller with a pulley at one end and triangular ridges along its length. The two pulleys are connected with a cord belt. As the implement is dragged the roller comes into contact with the soil and revolves and drives the roller in the seed box thereby regulating seed drop. There is also provision to operate the seed roller by a crank arrangement if desired.

SEEDER No. 4 (DE SOYSA)

THIS too is similar to number 2 and aims at simplifying the seed regulation mechanism. The seed box carries a sheet metal screen which regulates the seed flowing into the delivery compartment.

A shaft with rubber blades runs through the seed box. The seeder is dragged and at the same time agitation is effected by turning the crank handle of the shaft thereby feeding regulated quantities of seed into the tubes.

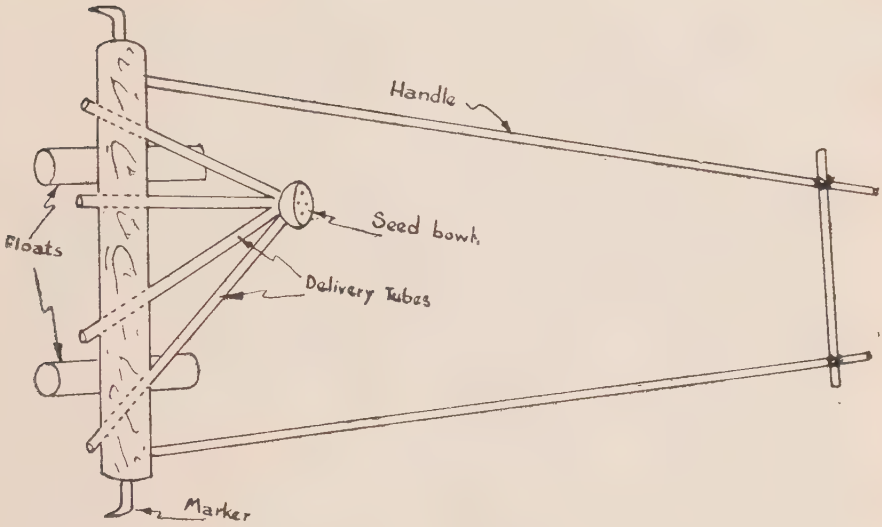
SEEDER No. 5 (WICKREMASEKERE)

IN this again as in numbers 3 and 4 the seed regulations received attention. The seed hopper is brought closer to the head piece and the shaft in the hopper carries wire fingers to brush the seed into the tubes. The rotation of the shaft is effected by a spider wheel at one end which rotates as the seeder is drawn backwards.

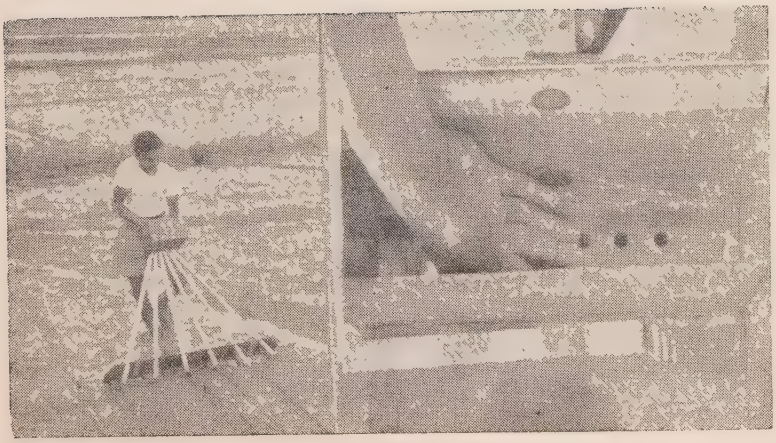
SEEDER No. 6 (THAMBIAYAH)

THIS implement except for modifications effected in regard to direction of movement in operation and seed regulation is similar to No. 2

The head piece in this is altered to a levelling board with furrow shoes behind which the seed tubes end. This permits the seeder being pushed as the operator walks forwards. The seed hopper carries a fitted wooden roller in the delivery compartment, which is cranked to effect feeding of the tubes. A brush cut out is provided to prevent chocking of the delivery mechanism. The lane between the two centre rows is increased to 11″ to permit forward movement of the operator.



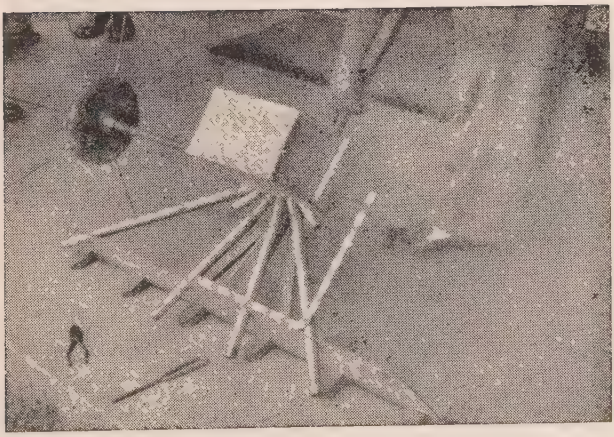
Seeder No. 1



Seeder No. 2

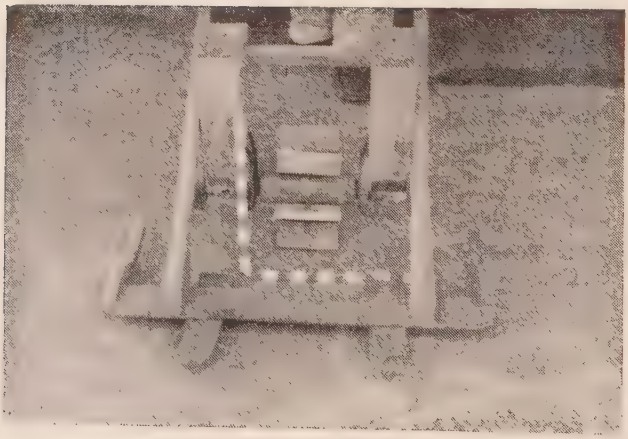
Seeder No. 3

Seeder No. 4



Seeder No. 5

Seeder No. 6



Seeder No. 7

SEEDER No. 7 (THAMBIAYAH)

THIS is an adaptation of a Japanese Model. The seeder rests on the field on its float shoes. As the seeder is pushed along the field, the paddles of the drive wheel come into contact with the mud and cause the seed drum to rotate. The rotating drum catches a small quota of seeds in each of the oval shaped recesses carved out in the drum and drops it into the furrows made by the float shoes. The float board, which also helps to level, prevents the seeder from bogging down. When the implement is pushed in the correct position the floating board surfs on the field. The operator walks in the lane left by the two rows of seeds. The seeding mechanism is principally an external force feed through a pitted roller.

SEEDER No. 8 (DIAS)

IN this model certain features are similar to those in number 7. The feed mechanism has been made more elaborate with provision for seed rate alteration. The seeder hoppers have been increased to four with a relative increase in the number of rows. The drive paddle wheel is suitably geared through wooden gear wheels to rotate the seed the drum. Delivery funnels lead out from the compartment in which the seed drum is placed.

SEEDER No. 9 (DIAS)

THE principal difference in this seeder to number 8 is the power transmission from the drive paddle wheel to seed drum which is through sprocket and chain arrangement. The lower end of the drive arrangement is partially covered with a mudguard.

SEEDER No. 10 (KARUNARATNE)

THIS implement has been designed on a multi-purpose basis and is convertible for use on high lands as well. The main parts of the seeder are the hoppers, seed drums and drive wheels. As the seeder is moved the rotation of the lugged wheels drives the seed drums on which are pockets to receive the seed. From the pockets of the seed drums the seed drops into the funnels and is delivered. Rubber facing on the bottom of the seed hoppers reduce injury to seed. Metal collars prevent wastage of seed drums. A slip ring arrangement allows for variation of size of pockets on the seed drum and seed containers

can be moved to reduce quantity delivered to the pockets. A sliding plate cuts off flow of seed and is useful in rounding corners or during transport of implement. Besides seeding, application of fertilizers is also possible. The implement has attachments for conversion for weeding operations and heavier wheels for use on high land.

SEEDER No. 11 (WICKREMASEKERA)

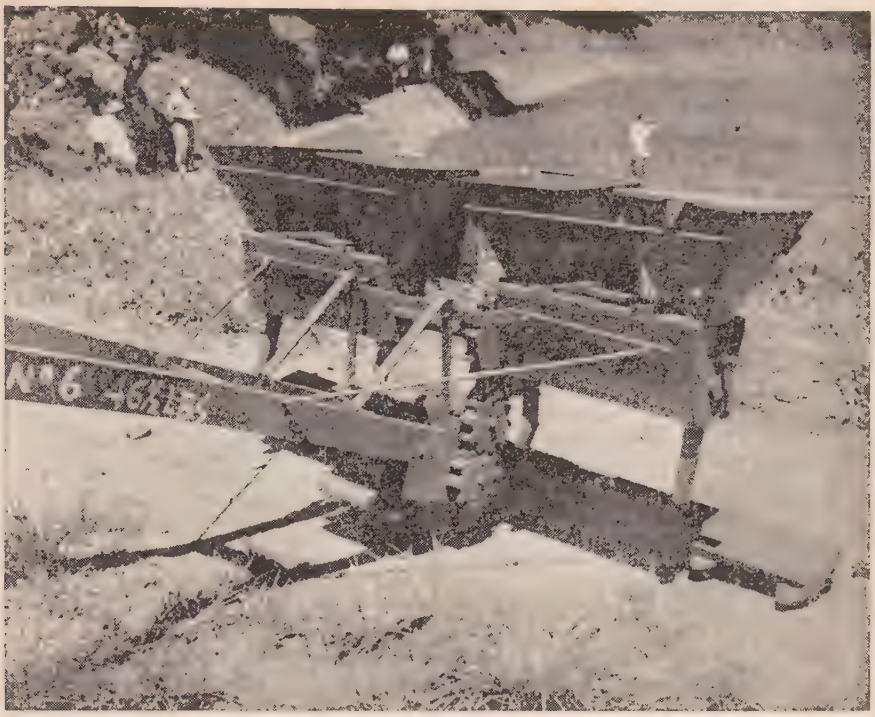
THIS implement is like a children's push cart. The hopper is a narrow, long box of " V " section placed between two 15 ins. diameter 6 ins. wide lugged wheels. The axle connecting the wheels runs slightly above the base where the sides of the box meet. Delivery exits for seed are provided along the front side of the box parallel to the centre line of the axle. About the centre of the delivery openings small brushes are fitted on the axle. As the seeder is drawn the seed is brush fed and is delivered through the exits along furrows caused by suitably placed wooden pegs. The angle at which the implement is held keeps the seed behind the axle line.

SEEDER No. 12 (MUNASINGHE JAYAWARDENE)

IN this device a number of seed boxes are clipped along a beam at the ends of which are markers to denote spacing between rows. The distance between the boxes can be varied to suit desired spacing of hills in the row. At the base of each box is a small opening (the size of which can be varied) through which seed drops into a " chute " fitted underneath. The beam is held parallel to and about two feet from the ground and tilted in the direction of the markers ; a few seed drop into the receiving end of the shoot and when tilted in the opposite direction the seed shoot out to the ground. The operation is repeated after moving the implement to the position indicated by the markers. This is operated by two persons.

All seeders except No. 1 were submitted for test by an agricultural implement testing board during the latter part of 1957. The Board consisted of Messrs. L. R. L. Perera (Chairman), F. Coleman, G. E. Bryce and L. R. Senaratne (Co-opted).

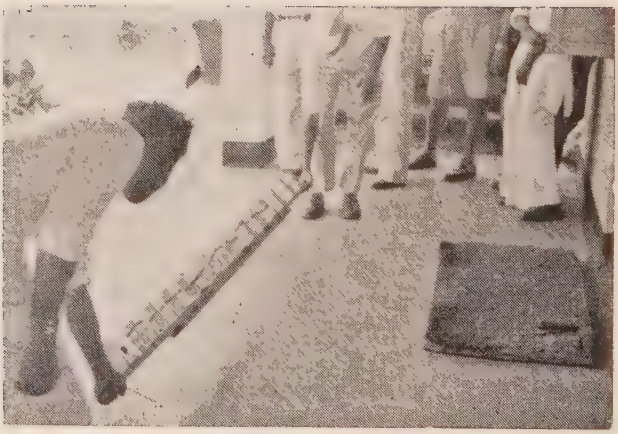
The board observed that most designs incorporated many of the desirable points ; every one is a good attempt and modifications should be done to approach the ideal. Seeders Nos. 2 and 7 have come closest to the ideal. Seeder No. 10 should be further modified to bring down cost of production and weight. Seeder No. 12 is understood to be covered by a patent by the designers.



Seeder No. 8

Seeder No. 9

Seeder No. 11



Seeder No. 12

Seeder No. 13

Seeder No. 14

During the period 1958 to 1959 Mr. F. Coleman (F. A. O.) and Dr. S. Niizeki (C-Plan) assisted by Mr. S. Thambiah devoted attention to this problem.

Mr. F. Coleman carried out investigations to—

(1) Eliminate backward walk of operator.

(2) Cause seed rate regulation independent of the skill of operator.

(3) Prevent seed metering arrangement injuring seed.

(4) Adjust power requirement to suit operator to work continuously.

(5) Reduce damage to level surface of the field during operation.

(6) Reduce weight and incorporate means of varying seed rate and to reach levels low enough.

The above were the cheap disadvantages obtained in the already existing designs.

SEEDER No. 13 (COLEMAN)

"THE mechanism finally developed comprises a horizontal drum, 25 to 35 centimetres in diameter and of a length suited to the width. The interior of the drum carries guide vanes which direct the seed placed within it, towards the two-end plates. The end plates have 6 to 8 apertures, close to their peripheries, and each aperture opens into a seed cup, whose volume can be altered by a shutter. The seed cups can be arranged to deliver the seed in front of the drum or to drop it behind."

The seed metering system seems to have been influenced by the arrangement in seeder number 12.

It is capable of seed rates ranging from .6 to 2.5 bushels per acre at 20 cm. row spacing. Besides this the arrangement was suitable for germinated seed with as much as 1 cm. of radicle with least injury. Of course with increased radicle length the seed rate is reduced owing to increased volume occupied by each seed.

This horizontal drum is placed in the centre of a 60 centimeter diameter sheet metal rim 10 to 15 cm. wide and supported by two discs. The rim and the supporting discs were made water-tight to permit floatation.

The wheel and 2-row seeding mechanism is fitted with a simple U shaped strip-iron yoke and wooden handle to push seeder by hand. Further prototypes developed made provision for furrowing, pressing the seed gently into the soil surface, elimination of guide vanes and reducing the cost of manufacture. It was being evolved so that light, single row units could be mounted in gangs if required. Possibilities of using this as an animal drawn implement with row spacing modification was also examined. Besides seeding, this arrangement would be suitable for fertilizer application. Messrs. D. P. R. Hettiarachchi and B. Ekanayake were associated with Mr. Coleman in the construction of these prototypes.

Dr. Niizeki was of opinion that the performance of a seeding device is conditioned by the properties of the soil, systems of water usage, and even the manner of sprouting the seed in different localities. The seeder should be able to deliver seed to get the optimum plant density desired with little thinning out or filling vacancies, but should be in rows suitable to use power off animals or midget tractors wherever possible for intercultivation and for introduction of single row harvesters in course of time. He listed (*a*) continuous drop seeding, (*b*) avenue spot seeding, (*c*) square spot seeding, (*d*) strip seeding and modification to double or triple avenues if animal or midget tractor power is to be taken into consideration.

Once the seeds are dropped according to the desired manner the field conditions should not disturb the seed. Hence the placement of seed on the flat, in furrows, in shallow depressions and pressing the seed placed on the flat gently into the surface were examined. The " staying " of seed is essential to prevent bird damage and seed drift in rainy weather. He was of opinion that strip seeding followed by wire—gauze rolling would be suitable in many areas.

He suggested five devices for seeding which are (1) Frame type square planter, (2) Frame type Drill, (3) Drum type seeder, (4) Octopus type seeder, and (5) Strip seeder. Considering the weed problem in Ceylon, he emphasised that square or avenue spot seeding which permits two way inter cultivation may be most suitable for intensive cultural treatments to the crop.

Digressing from the main subject it will be useful to refer to some of the observations of Dr. K. Sakai, C-Plan expert who was attached to the Division of Botany and had occasion to conduct a series of experiments on dibbling paddy during his stay in the Island from 1957 to 1959. He has stated that, " Dibbling looks to be a quite effective

method of rice cultivation for increasing yield, because dibbling over-yields broadcasting, row sowing and probably in some cases even transplanting.....

If the plant density is so high as 16 or 32 plants per hill, the plants become susceptible to blast disease, as susceptible as those row sown.....

In dibbling with a suitable plant density, plant height, panicle size and straw thickness became larger than in row sowing. In addition sterility goes down in dibbling in comparison with row sowing. Tillering also increases due to being dibbled.....

In respect of spacing between hills, plant density within hills, &c., I am at present only in a position to make the following suggestions :—

(A) The recommendable inter-row and inter-hill spacing will be 10 in and 8 in. to 10 in. respectively, taking into consideration the double use of a rotary weeder lengthwise and crosswise. As a matter of fact, the highest yield was obtained at the inter-hill spacing of 8 in. or 10 in.

(B) The recommendable plant density will be between four and 8 plants per hill or between 5 and 10 seeds per hill. The most suitable number of plants or seeds planted per hill, however would probably differ from variety to variety, and from location to location or properly speaking, it may vary according to different environmental conditions, namely, soil condition, fertility of the soil, &c. In this connection further experiments are required.

(C) For the practical purpose, it is a very urgent matter to construct a dibbling machine adapted to the above conditions..... "

The designs of Dr. Niizeki and modifications effected on other seeders are discussed briefly :—

SEEDER No. 14 (NIIZEKI)

THIS mechanism consists of a grooved roller fixed under a seed box in a manner, that, as the roller rotates by the power transmitted through the two wheels, when pushed, seed delivery occurs. Metal slip bushes can be moved on the roller to alter width of strips and spacing between strips.

SEEDER No. 15 (NIIZEKI)

AN octagonal metal drum with two octagonal wooden rims acting as wheels give the necessary clearance and form the main unit. The drum itself is made in two halves and can be opened for filling seed. On the 8 faces of the drum are placed 16 tube exits to deliver the seed. The internal surface has catch projections and ribs so arranged as to direct the seed to the delivery tube exits. The two halves of the drum are so meshed that it is possible to alter spacing by about 2 in. if necessary. The axle with a handle and furrow opener shoes bears the drum. The seeder is a push type with the wheel rims acting as markers.

SEEDER No. 16. (NIIZEKI)

THIS planter consists of a hectagonal, skeletal, prismatic frame divided into four sections along its length. Each section carries a unit comprising a seed container with a delivery funnel and a circular metal disc with 7 radial extensions on which seed cups are fixed. The seed containers are slung on a loose central axle and the disc bearing the cups are fixed to the frame through tube shafts. The frame can be rolled on the soil surface by pulling backwards with the handle. As the frame rolls the seed cups pick up the seed in the containers and deliver them through the funnels thereby depositing about 12 or 15 seeds per spot. The spots of seed can be laid on the square 10 in. × 10 in. or avenue 10 in. × 6 in. to 8 in. pattern. The handle can be adjusted to vary with the operator's height. In the trials carried out the crops sown with the aid of this seeder permitted intercultivation length and crosswise when a high degree of weed control was achieved. The original model was modified to the present version to reduce weight and cost of production.

The octopus type seeder is very similar to the model used in the Hokkaido area in Japan. One was turned out for seeding experiments. This and the frame type drill are not dealt with here.

SEEDER No. 17 (COLEMAN-MODIFICATION)

SEED drums are the same as in No. 13. Two drums are supported by a light pipe axle borne on the drive wheels. The wheels are 16 in. in diameter with 3 in. wide sheet metal rims with 12 wooden slat lugs which also served as markers.

SEEDER No. 18 (COLEMAN-MODIFICATION)

IN this too the seeding mechanism is the same as No. 13. A set of 3 are mounted on an axle. The unit rests on a floating board with " shoes " for making furrows. The axle with the seed container drums derive their motion as the two end paddle wheels, which are partially immersed in the mud, revolve.

The Implement Testing Committee comprising Messrs. S. B. Gupta (Chairman), E. Katoh, C. R. Karunaratne and S. Thambiayah (Secretary) have further tested seeders number 2, 7, 10 and 13 to 18. With the commencement of the implement factory project at Welisara it was necessary to view the designs in a different light since mass production facilities and up-to-date machines would bring down costs. Earlier production was chiefly through village smithies. It should also be possible to incorporate certain mechanisms to increase effeciency with relatively little increase in cost of production.

The committee decided to drop all models that did not come up to minimum requirements. After preliminary tests a restricted number of each suitable model will be produced through the implement project and tested in all departmental farms before finally recommending them to the extension service. Seeders Nos. 16 and 17 have been passed on for preliminary production. With the varying conditions in the Island one model of seeder will not suffice. A number of models may be necessary to meet this need and to keep up with changing cultural practices that will show up.

APPENDIX I

The points considered desirable in an ideal seeder :—

(1) Low cost.

(2) Light in weight.

(3) Simplicity of design.

(4) Ability for operation by one person.

(5) Designs enabling operator to work in a comfortable and least tiring manner.

(6) Minimum replacement of parts under careful storage and use.

(7) Least damage to the prepared field by the implement or operator during work.

(8) Capacity to work under variable field conditions.

(9) High speed of operation.

(10) Uniformity of seed delivery.

(11) Minimum injury to seed used.

(12) Low draught.

(13) High percentage of viable seed sown.

(14) Possibility of adjusting spacing and seed rates.

(15) Possibility of placing seed in furrows or gently pressing the sown seeds into the soil surface if required.

APPENDIX 2

References :—

(1) Report of the 3 officers of the Department of Agriculture sent to Japan to study rice cultivation—1955.

(2) Tropical Agriculturist. Volume CXII 1956.

(3) Tropical Agriculturist. Volume CXIII 1957.

(4) Row sowing as an alternative to transplanting—Francis Coleman.

(5) A report of the work done by Dr. Kan-Ichi Sakki.

4——J. N. B 18584 (11/59)

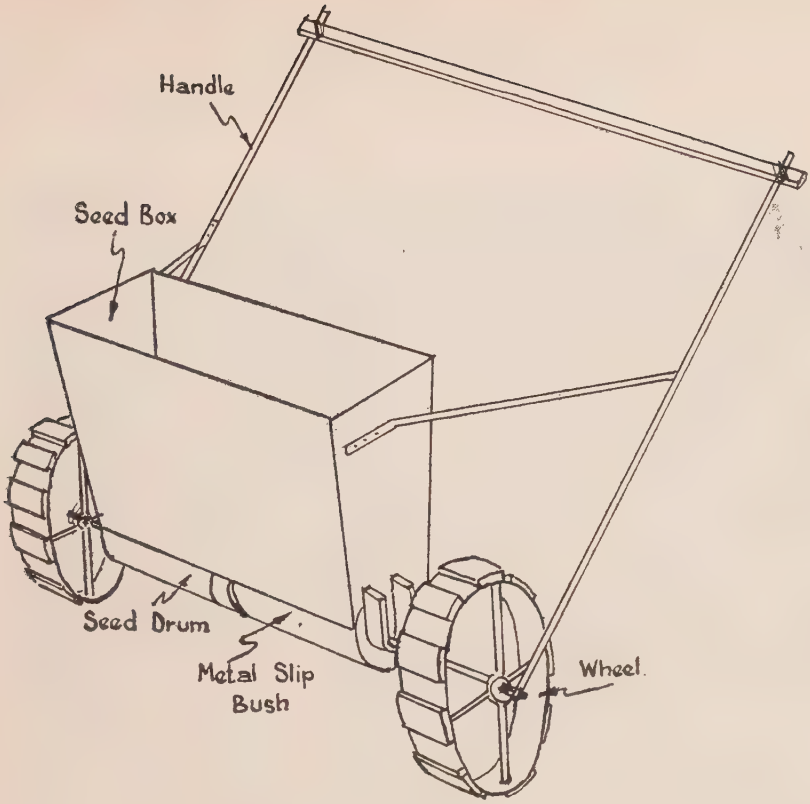
APPENDIX 3

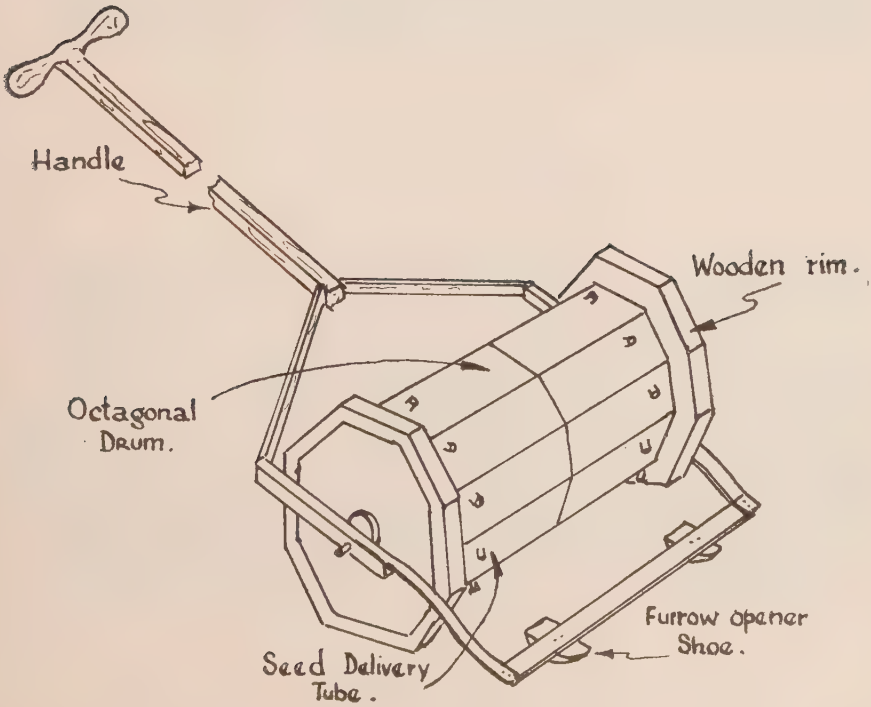
Seeders	*Weight in lb.*	*Estimated Cost*	*No. of Rows*	*Field damage (10 Marks for Best Conditions)*	*Speed of operation (approx.) acres per 8 hours*	*Quantity of Seed Delivery. Per Acre in Bushel*	*Evenness of Sowing*	*Operations and Draught*	*Row Spacing*	*Remarks*
		Rs. c.								
Seeder No. 2 (John Pulle)	9·75 lb.	15 0	6	8	1·56	1·42 (Variable)	Fair	Easy for skilled operator	8″	Backward travel. Seed agitation by hand
Seeder No. 3 (Simion)	20 lb.	18 0	5	4	—	7·98	Poor	Slow and awkward	8″	Drive mechanism in effective
Seeder No. 4 (De Soysa)	12 lb.	18 0	6	5	1·35	·94	Poor	—	8″	Delivery mechanism ineffective
Seeder No. 5 (Wickremasekera)	16 lb.	20 0	6	5	—	1·75	Poor	Direction difficult	8″	do.
Seeder No. 6 (Thambiayah)	19 lb.	22 0	6	9	1·9	—	Poor	Pushed type easy	8″ middle row 11″	Brush cut out gets choked
Seeder No. 7 (Thambiayah)	10 lb.	15 0	2	8	1·47	·5	Fair	do.	15″	Tendency for seed injury with wear of seed drum

Seeder No. 8 (Dias)	46½ lb.	60 0	4	5	1·00	·94 Adjustable	Poor	Too heavy	12″	Tendency for gears to get chocked with mud
Seeder No. 9 (Das)	48½ lb.	75 0	4	3	1·5	2·8 Adjustable	Poor	do.	12″	—
Seeder No. 10 (Karunaratne)	46 lb.	50 0	3	9	2·58	2·7 Adjustable	Fair	Pushed type Easy	10″	Weight disadvantageous
Seeder No. 11 (Wickremasekara)	22 lb.	25 0	6	6	0·75	2·5	Poor	Heavy slippage of wheels	9″	Tendency to get bogged in the mud
Seeder No. 12 (Moonasinghe & Jayawardane)	18 lb.	15 0	1 row 14 hills	9	1·25	0·8 Adjustable	Satisfactory	Two men operated	Adjustable to required distance both ways	Continuous work tiresome owing to position of work
Seeder No. 13 (Coleman)	20 lb.	20 0	2 per unit	8	0·75	0·6 to 2·5 Adjustable	Satisfactory	Slippage occurs	9″	The Gause wheel tends to drag delivered seed. Mud tends to rundown into seed cups
Seeder No. 14 (Niizeki)	17 lb.	15 0	2 strips	7	0·4	2·7	Poor	Slippage occurs	Variable width of strips and between strips	Tendency for seed injury and sometime mud splashes on drum

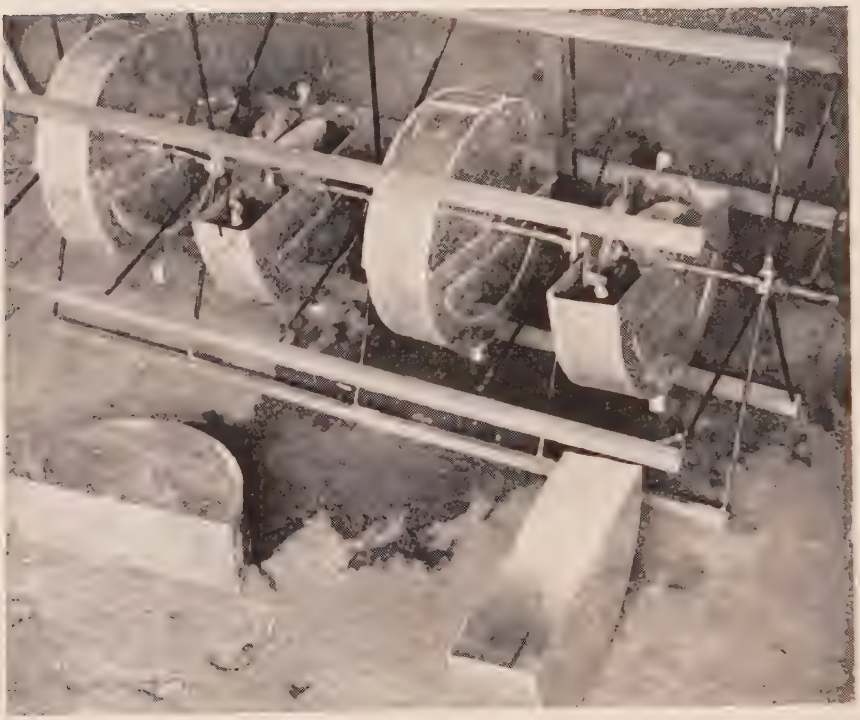
APPENDIX 3—*contd.*

Seeders	*Weight in lb.*	*Estimated Cost*	*No. of Rows*	*Field damage (10 Marks for Best Conditions)*	*Speed of operation (approx.) acres per 8 hours*	*Quantity of Seed Delivery. Per Acre in Bushel*	*Evenness of Sowing*	*Operations and Draught*	*Row Spacing*	*Remarks*
		Rs. c								
Seeder No. 15 (Niizeki)	23 lb.	20 0	2	4	0·8	2·8	Poor	Exits too close to soil surface	10″ to 12″	Tendency for wheel slips
Seeder No. 16 (Niizeki)	20 lb.	45 0	4 in hills	9	1·00	0·8	Satisfactory	Easy to operate	Hills 10″ × 10″ or 10″ × 6″ to 8″	Very suitable for square planting
Seeder No. 17 (Coleman modification	18 lb.	20 0	4	9	2·00	1·0	Fair	Regulated seed drop	9″	Light-push type
Seeder No. 18 (Coleman modification)	26 lb.	30 0	6	8	2·25	1·3	Fair	—	9″—Centre 11″	Not effective when soil not settled



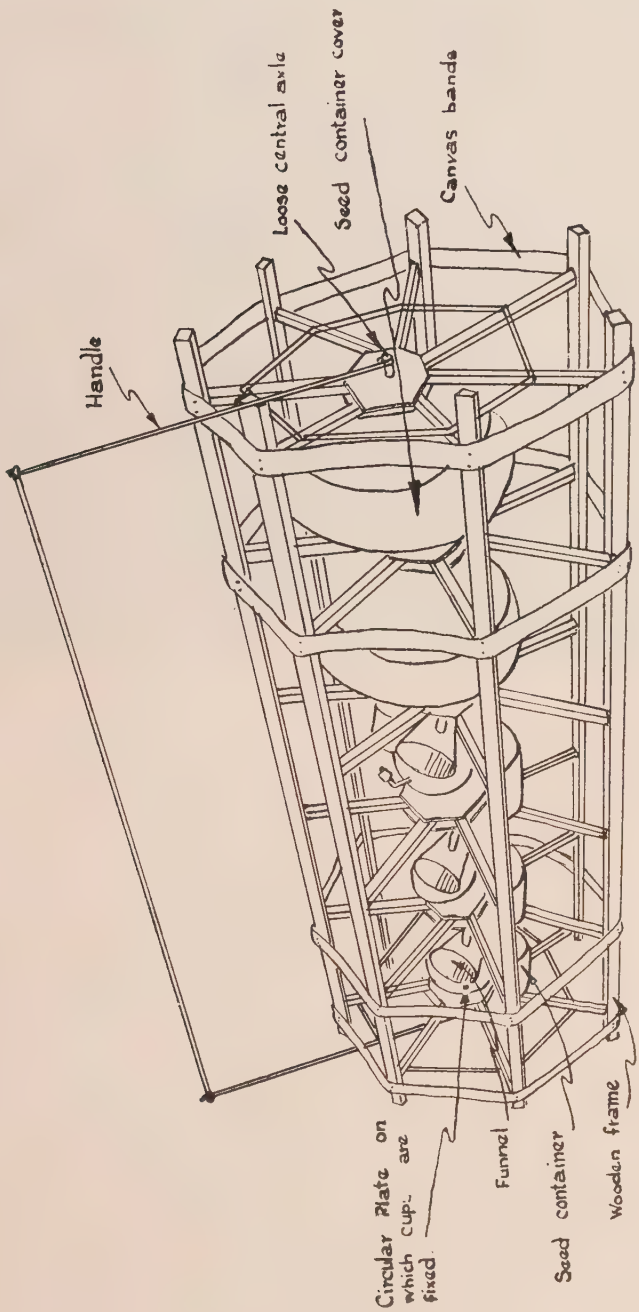


Seeders Nos. 14 and 15



Seeder No. 16

Seeder No. 17



Square Planter

Seeder No. 18

STUDIES OF *EMPOASCA DEVASTANS* DIST. (FAM. JASSIDAE, ORD. HEMIPTERA), A NEW PEST OF CACAO CAUSING DEFOLIATION, AND ITS CONTROL

By H. E. FERNANDO,

(*Entomologist, Department of Agriculture, Peradeniya, Ceylon*)

INTRODUCTION

DAMAGE caused by leafhoppers to crops include such affects as leaf spotting, more extensive injury known as "hopperburn" and two types of systemic injury which include wilting and virus-like symptoms (Carter 1952). *Empoasca fabae* (Harris) is by far the most notorious among the leafhoppers for its damage known as "hopperburn" caused to potatoes during its feeding (Peterson and Granovsky 1950) and serious damage caused to legumes such as alfalfa (Melder 1941, Johnson 1934, Smith and Poos 1931, Granovsky 1930). *Empoasca flavesceus* Fab. prevented the establishment of cotton growing in Luzon (Cendena *et al* 1947.) as its feeding caused the wilting and drying of the leaves of that crop. A similar wilting, but of peach seedlings, has been noted by Kunkel (1933) to be caused by the feeding of the leafhopper *Macropsis trimaculata* Fitch while Severin *et al* (1945) have reported aster yellows and curlytop virus-like symptoms in sugarbeet caused by the toxins in the feeding secretions of the leafhopper *Zerophloea vanduzeei* Law. *Empoasca devastans* Dist. the species dealt with in the invstigations being reported on, is the leafhopper responsible for extensive leaf damage to cotton in the Punjab (*Afzal* and *Ghani* 1953).

In June 1956, during sporadic rains following a severe drought, the young leaves of cacao plants in the Dumbara Valley were observed to be malformed, abnormally coloured and to shed prematurely. Examination of the affected leaves in the early stages of damage revealed the presence mainly of nymphs of a Jassid and thrips belonging to the species *Scirtothrips dorsalis*. Occasionally a small greenish coloured adult Jassid with a black dot at the posterior end of each of the forewings was noted on the leaves of affected cacao plants. This

leafhopper and the nymphs noted on cacao plants have been indentified as belonging to the species *Empoasca devastans* Dist. by the Commonwealth Institute of Entomology, London. The investigations reported upon in this paper were undertaken with a view to establishing the causal agent of the cacao leaf malformations and other pathological symptoms and having established the causal agent to investigate the basis whether physiological or otherwise for the damage caused and also to study the control of the insects involved.

DESCRIPTION OF SYMPTOMS PRECEDING PREMATURE LEAF FALL AS OBSERVED IN THE FIELD

THE nymphs of *E. devastans* are invariably located on the lower surface of young leaves. Thrips of the species *S. dorsalis* on the other hand predominantly infest the upper leaf surface in the depressions on either side of the veins. Young leaves or flushes of cacao plants appear soon after rains. These flushes are usually deep copper coloured at first and on maturing gradually turn green in colour. The symptoms of abnormal development, associated as shown later with *E. devastans* attack, which precede premature leaf fall usually take the following sequence :—

1. Young flushes become boat-shaped with the leaf margin bending downwards,
2. the leaf tip withers, turns brown and dies while simultaneously necrosis of patches of lamina at the leaf margins begins to develop,
3. sections of larger veins may be distinctly necrotic with the adjacent leaf-tissue alive and growing resulting in marked outward bulges of lamina in these regions,
4. the leaves turn deep pink in colour with all traces of chlorophyll suppressed and become relatively brittle at the same time,
5. the leaves become yellowish or pinkish brown in colour and as the brown colour becomes more marked the leaf is shed.

Frequently however the pathological symptoms on leaves do not pass beyond stage 2. In such cases the leaf may turn deep pink only in patches and gradually a chlorotic green coloration develops in the leaf which gradually matures. Such leaves show necrotic patches of tissue and do not survive as long on the plant as do normal leaves (Plates 1A and 1B).

Plate 1A and 2B—Cacao leaves remaining on trees after *E. devastans* attack in the field. Note loss of turgor of leaves, undulating leaf surface, necrotic parts of lamina and paucity of leaves on stem which shows position of shed leaves.

CAUSAL AGENT OF CACAO FLUSH DEFOLIATION

OBSERVATIONS in the field showed that particularly nymphs of a species of leaf hopper, subsequently identified as *Empoasca devastans* Dist. and to a lesser extent, thrips of the species *Scirtothrips dorsalis* were found on leaves showing the symptoms preceding premature shedding. Where neither insect was present as such, the cast skins of leafhopper nymphs were usually found on damaged leaves. Infestation tests were therefore carried out using these two insects in varying numbers on young flushes of healthy cacao seedlings to study the reactions of the leaves to feeding by these two insects.

Four cacao seedlings about 18 inches tall were used for infestation tests with thrips. All mature or maturing leaves in contact with the few tender leaves to be infested were cut off. Late instar nymphs of *S. dorsalis* from cacao plants were collected in the field and brought to the laboratory immediately before the infestation experiments. Thrips were transferred on to the flushes of test plants with the aid of a small camel hair brush which was slightly moistened. *Scirtothrips dorsalis* is found predominantly along the grooves on either side of the veins and veinlets of the upper side of the cacao leaves. Infestations of this insect were therefore made on the upper leaf surfaces of the young flushes of test plants.

Two tender leaves, about 4 to 6 inches long, of the 4 test plants were selected for infestation which was carried out at the rate of 5, 15, 50 and 75 advanced nymphal thrips per leaf. After infestation the plants were enclosed in insect-proof cages.

Daily observations were recorded of the survival of the thrips and the reactions of the flushes to thrips feeding. Within 24 hours of the infestation a district pink coloration developed on either side of the veins where the thrips had fed. Glossy, transparent areas of varying sizes appeared on some of the parts of the leaf lamina where thrips were located. These transparent areas were fringed by a zone of pink lamina. Within 48 hours of infestation the transparent areas of lamina turned brown and within 72 hours these areas were completely brittle. Within 5 days these browned, brittle areas cracked and disintegrated. As the attack continued the leaves were hardening. The extent of development of necrotic tissue areas and pink coloration along the veins was more marked where higher numbers of thrips were used per leaf. When the leaves completed development they presented a tattered appearance with the areas of necrotic leaf tissue completely fallen off.

For infestation experiments using the leafhopper, *Empoasca devastans* eleven cacao seedlings about 18 inches tall were selected.

One tender or one hardening young leaf was maintained for infestation on each plant and the remaining such leaves were clipped off at the petiole. All fully mature leaves which came in contact with the test leaf of each plant was also clipped off. The test leaves were all free of any abnormal symptoms before the infestation by leafhoppers. Of the eleven plants selected, two were maintained as uninfested checks and nine used for infestation with leafhoppers at various rates per leaf. Leafhopper nymphs were collected from the field on the day of the infestation experiments. The test leaves were measured from base to tip and infestation with leaf hopper nymphs, classified either as very young or mature, was done at varying rates per inch of leaf as shown in Table 1, in which the effects of these infestations on growth rate of cacao flushes is presented. This data should not be taken to represent precise information on the effects of feeding of E. *devastans* nymphs on the growth rate of young cacao leaves on account of the small numbers of leaves used in the tests. It should rather be taken to convey an overall picture of the growth retarding effect upon young cacao leaves due to feeding by this bug. Clearly, both immature and mature nymphs of *E. devastans* are capable of inducing retardation of the growth of the young leaves and generally this effect is more pronounced the larger the number of nymphs infesting the leaf and the younger the leaves when infestation commenced. The other symptoms of leafhopper feeding which developed concommitantly with the retardation of growth rate cannot be tabulated. They are therefore described in detail below.

Bugs were noted to feed only on the veins as can be seen in Plate 2 where an adult *E. devastans* is pictured during feeding. Nymphs introduced on to the test leaves commenced feeding mainly on the veins at the region about two inches around the leaf tip and along the leaf margin and then gradually withdrew towards the petiole and midrib as the tissue near the leaf tip or leaf margin became necrotic. This habit of the bug is clearly visible not only by the location of feeding bugs and developing necrosis but also by the prsence of opaque sections of the veins at the leaf tip and margins when the infested leaf is viewed through transmitted light.

The first effect to be noted in a leaf infested by *E.* devastans nymphs is a gradual loss of turgor which is quite marked within 24 hours of infestation. This loss of turgor does not proceed far enough in the initial stages for the degenerative changes noted to be categorized as a wilting.

At the same time as the loss of turgor develops (within 24 hours of infestation with bugs) if the leaf is viewed through transmitted light portions of veins in the region of the leaf tip and leaf periphery

TABLE I—*Effect of Infestation of young or Mature Nymphs of* E. devastans *on growth rate of young or maturing cacao leaves*

Plant Number	*Condition of Leaf before Infestation*	*No. of Leaf Hoppers per inch Leaf length*	*Stage of Maturity of of Leaf Hopper Nymphs used*	*Length of Leaves in inches*		*Per cent. Increase of Leaf length in 1 Week*
				Before infestation	*1 Week after infestation*	
1	Tender	0·5	Very young	4·0	9·5	137·5
2	Tender	0·5	Mature	6·0	10·0	67·7
3	Tender	1·0	Very young	5·0	7·0	40·0
4	Hardening	1·0	Very young	6·5	7·75	19·2
5	Tender	1·0	Mature	3·5	5·5	57·0
6	Hardening	1·0	Mature	5·0	7·0	40·0
7	Tender	3·0	Very young	6·0	8·75	45·8
8	Hardening	3·0	Mature	4·5	5·75	27·7
9	Tender	6·0	Mature	5·0	6·25	25·0
10	Tender	Uninfested Check	—	4·0	10·0	150·0
11	Hardening	Uninfested Check	—	6·0	8·5	41·7

Plate 2.—Adult, *E. devastans,* feeding upon lower surface of cacao leaves.

will be observed to be opaque in comparison to normal veins which are translucent. Examination of such opaque veins from the ventral side would show that they are light to deep brown in colour and are clearly collapsed as compared to other normal veins which are light green and turgid in appearance. Simultaneously with the loss of turgor the leaf tip and margins bend backwards or downwards (Plate 3 A). Particularly on tender flushes, minute, glossy, transparent spots about 1 to 3 mm in diameter surrounded by a pinkish zone, develop within 24 hours of feeding by the bugs.

Within 48 hours of feeding the downward curl of the leaf tip and margins becomes more markd (Plate 3 B). Portions of the intervenal leaf surface show marked bulges due to the presence of dead veins bordering zones of growing leaf tissue. The leaf tip is usually necrotic and parches of necrotic leaf tissue develop along the leaf margins and gradually extend towards the midrib.

Within 72 hours the leaf has become deeply distorted boatshaped and the surface is bulging in areas of active growth bounded by dead veins (Plates 3 C and 3 D). The leaf tip and margins show extensive

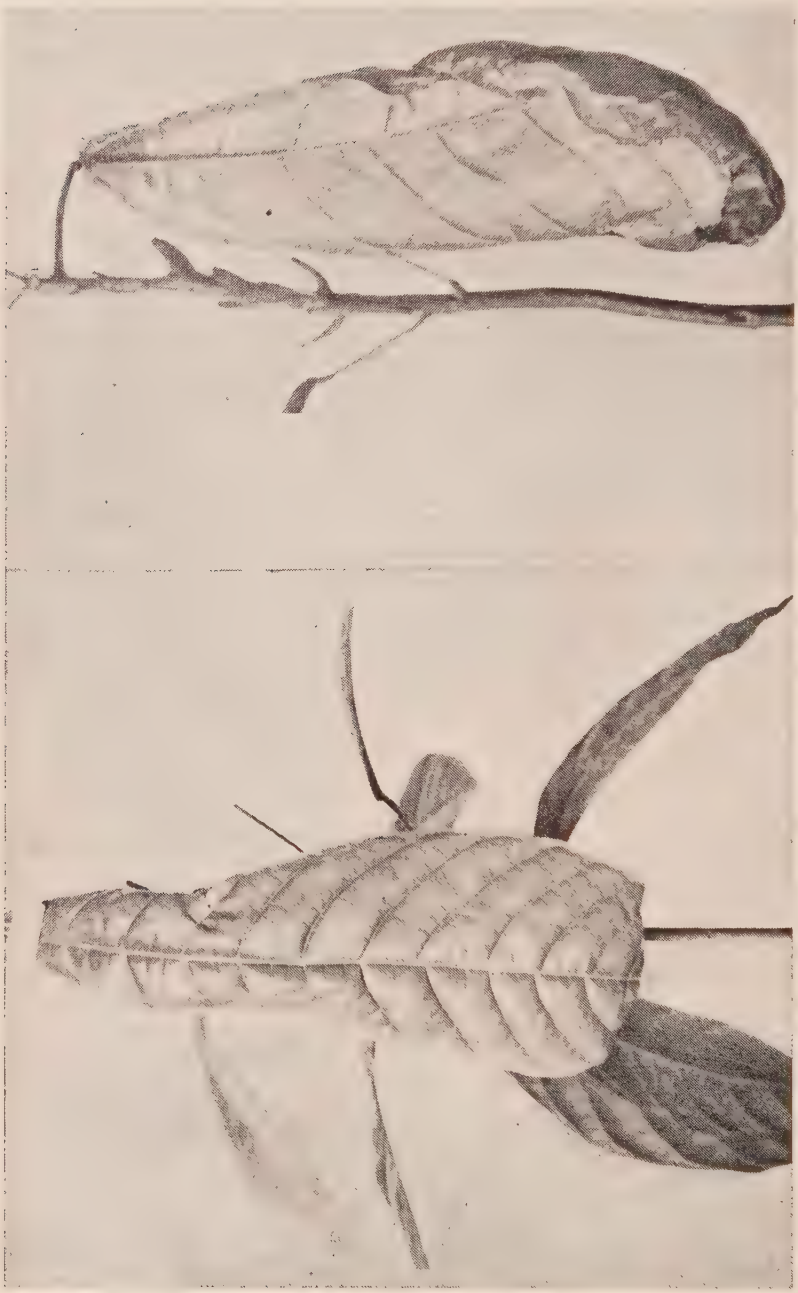
necrosis which is more marked where tender leaves were infested with bugs. The veins which have been fed upon and are collapsed are bordered by a chlorotic zone. The general leaf surface, where no necrosis or chlorosis is apparent, has developed an extensive light pink coloration and traces of green diluted by the pink coloration are present only in patches.

Within 96 hours of infestation the necrosis and distortion has spread closer towards the midrib in the case of tender leaves and the pink coloration is more extensive. Within about 8 days of continued feeding by leaf hoppers the leaf is to a large extent necrotic or pink coloured and usually drops off. It should be mentioned here that the younger the leaf and the larger the number of leaf hopper nymphs infesting the leaf the quicker is the onset and development of the symptoms described above. In the case of maturing leaves infested with leaf hoppers symptoms of damage are less marked and slower to develop. Generally where hardening leaves have been infested by leaf hopper nymphs, a certain amount of necrosis of veins accompanied by chlorotic zone and concommitant buckling of leaf surface results before the leaf has completely hardened by which time the leaf hoppers have either matured or migrated to younger leaves. Where tender leaves were infested with leaf hoppers removal of the latter before the entire leaf surface turns pink and brittle usually results in a mature undersized leaf with chlorotic patches intermingled with green patches. Such leaves remain a longer period on the plant than heavily attacked leaves but fall earlier than unattacked leaves. This series of experiments proved beyond doubt that the leafhopper *E. devastans* was responsible for the distortion, reddening and premature falling of cacao leaves.

POSSIBLE EXISTENCE OF A DIFFUSIBLE TOXIN IN E. DEVASTANS SALIVARY SECRETIONS

THE effects of feeding by *E. devastans* on young cacao leaves were so rapid and spectacular that it appeared likely that a highly diffusible toxin was present in the saliva of this bug. To check this possibility leafhopper nymphs were closed at the rate of 3 per circular leaf cage of young cacao leaves for periods of 12, 24 or 36 hours and the leaf hoppers removed at the end of these time intervals. The leaf areas upon which leaf hopper feeding was permitted were observed carefully for any subsequent changes. On removal of the leaf hoppers the area exposed to the insects appeared discoloured and somewhat water-soaked. Within 48 hours these areas had turned light brown and the veins were opaque when viewed in transmitted light. Within

Plates 3A and 3B —(Left) young cacao leaf 24 hours after attack by *E. devastans* nymphs (Right) same leaf 48 hours after infestation and feeding by nymphs.



Plates 3C and 3D.—Same leaf as in 3A and 3B 72 hours After infestation and feeding by nymphs of *E. devastans.*

72 hours these areas were deeper brown and fully dried. Eventually these areas fed upon by leaf hoppers in the circular cage were shed leaving circular holes in the leaves. The most notable feature of the damage caused to the young leaves in this experiment by the caged leaf hoppers was that it was restricted to the circular area exposed to leaf hopper feeding and did not extend beyond it (Plate 4). Clearly therefore a systemic toxin was not involved.

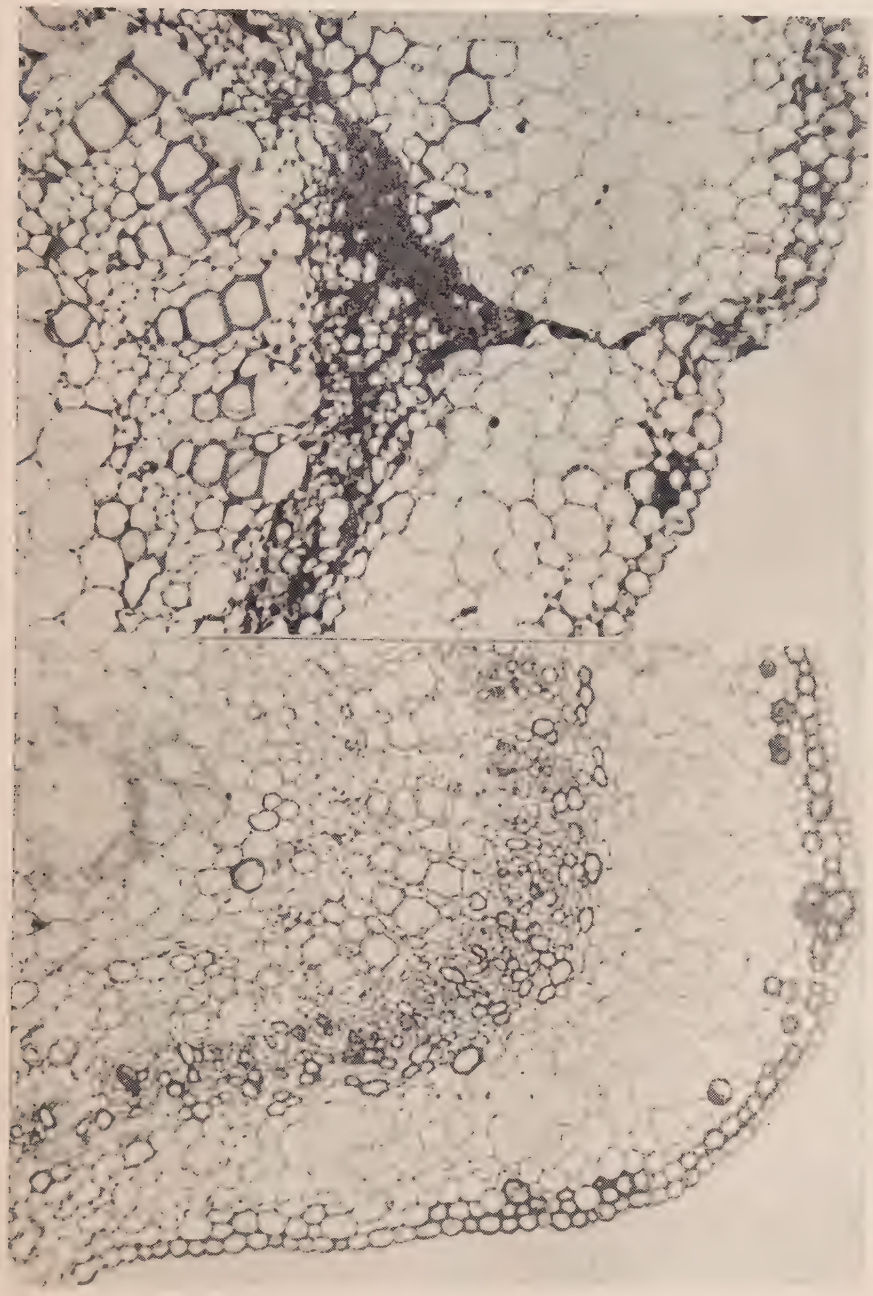
HISTOLOGICAL STUDY OF E. DEVASTANS DAMAGE TO YOUNG CACAO LEAVES

CACAO leaf tissue exposed to feeding by *E. devastans* was prepared for histological study by fixation in Carnoy's Fluid No. 2 Formula, (Smith 1926). Staining in saffranin in 90 per cent alcohol was found satisfactory for studying the histological damage caused by *E. devastans* feeding.

Plate 4.—Portion of young cacao leaf showing effects of localised feeding by *E. devastans*

A series of photomicrographs of transverse sections across vascular bundles of the cacao leaves are presented in Plates 5 A to E and Plates 6 A and 6 B. In earlier phases of this study leaf tissue was fixed for sectioning about 24 hours after feeding by leaf hoppers. Plate 5 B is a section from such a leaf across a feeding puncture of *E. devastans*. Comparison of this section with that in Plate 5 A, which represents a portion of a vascular bundle and bundle sheath of a normal young cacao leaf, will show that the parenchymatous cells of the bundle sheath of the attacked leaf are collapsed and empty while the phloem cells are either collapsed or replaced by a deeply staining amorphorus mass. A deeply staining tract can also be seen traversing the parenchyma into the phloem. This represents a feeding tract of the stylets of *E. devastans*. A feeding tract as clearcut and deeply staining as the one represented in Plate 5 B is rather the exception than the rule as it is present usually in only about 1 per cent. of the sections where feeding by this bug has taken place. Clearly however, the phloem is the most drastically affected tissue in the vascular bundle by *E. devastans* feeding. The pallisade cells or the spongy mesophyll is not attacked by this insect.

As earlier workers studying the damage to alfalfa caused by the potato leaf hopper, *E. fabae,* had concluded that the deeply staining material seen within the feeding tract and the phloem region of sections, fed upon by this bug, was a salivary secretion, studies were conducted to elucidate its nature in cacao leaves fed upon by *E. devastans*. Three mature nymphs of *E. devastans* were caged on circular areas of leaf of 1 centimetre diameter surrounding a vein. Feeding was permitted in all cases only for three hours and the leaf hoppers removed from the leaf cages. The portions of the leaf lamina exposed to the leaf hoppers within the leaf cages were cut out and fixed in Carnoy's fixative (*a*) at the end of the three hours feeding by the leaf hoppers (*b*) 6 hours after initial feeding by the leaf hoppers (*c*) 12 hours after initial feeding by the leaf hoppers and (*d*) 24 hours after initial feeding by the leaf hoppers. The sections obtained from this series of tests are shown in Plates 5C, 5D and 5E. At the end of three hours of feeding by the leaf hoppers, parenchymatous cells of the sheath of the vascular bundle though empty in patches, are still not badly collapsed. Phloem cells are empty (but not collapsed) in portions and the cell walls stain more brightly



Plates 5A and 5B.—(Left) Transverse section across vascular bundle of normal young cacao leaf. (Right) T. S. across vascular bundle of young leaf 24 hours after attack by *E. devastans.*

Plates 5C and 5D.—(Left) T. S. across vascular bundle of young leaf fixed at the end of 3 hours feeding by *E. devastans*.
(Right) T. S. across vascular bundle of young leaf fixed 3 hours after a 3 year feeding period of *E. devastans*.

Plate 5E.—T. S. across vascular bundle of young leaf fixed 6 hours after a 3 hour feeding period by *E. devastans.*

than the normal phloem cells. There is only the slightest trace of the deeply staining amorphous substance present in the region of the phloem cells (Plate 5C).

At the end of 6 hours after initial feeding and 3 hours after removal of the leaf hoppers a section of the leaf (Plate 5D) shows greater collapse of the parenchyma around the vascular bundle and collapse of the empty phloem cells. The deep staining amorphous substance in the region of the phloem tissue is more marked.

At the end of 12 hours after initial feeding by leaf hoppers and 9 hours after removal of the bugs from the leaves a section of the leaf (Plate 5E) shows very extensive collapse of the parenchyma of the bundle sheath and much more of the amorphous deep staining

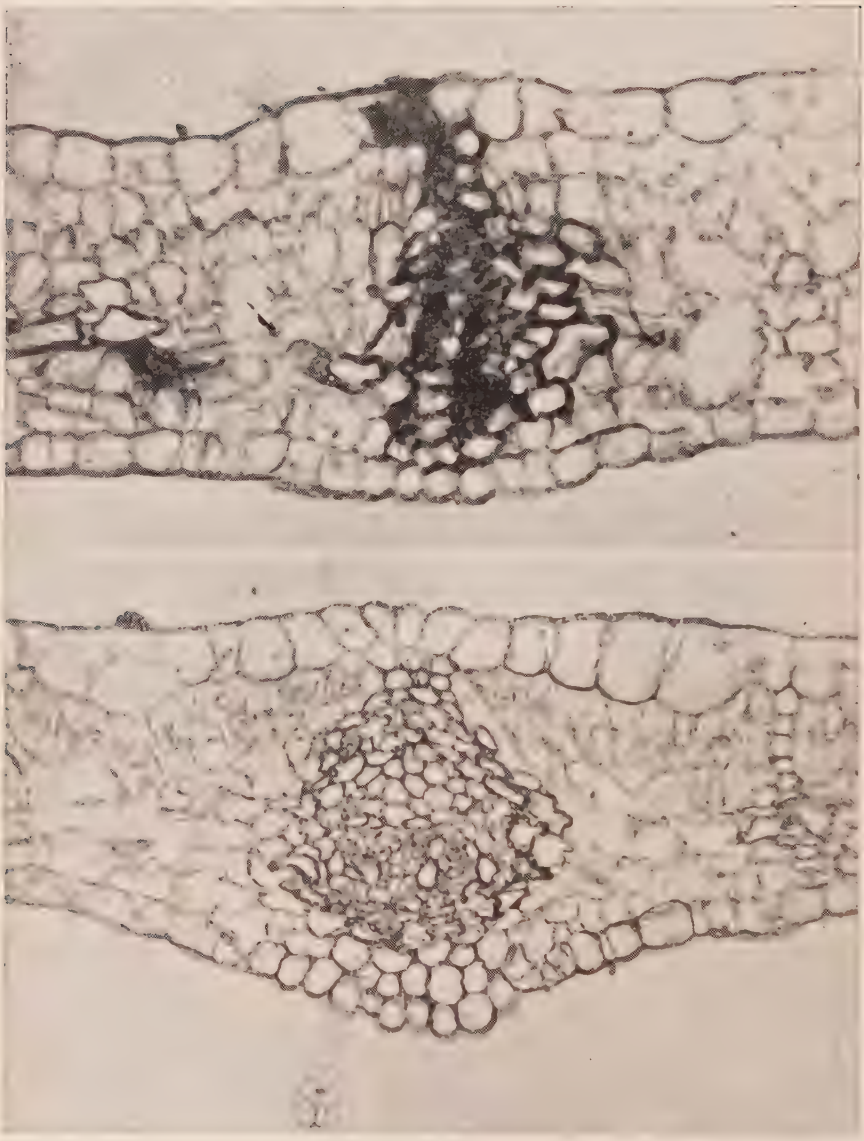


Plate 6A.—(Top) T. S. across small vascular bundle of young leaf fed on by *E. devastans* from the upper leaf surface.

Plate 6B.—(Bottom) T. S. across small vascular bundle of young cacao leaf 80 microns away from point of feeding by *E. devastans* shown in plate 6A.

substance in the region of the phloem. Twenty-four hours after feeding and 21 hours after removal of the bugs from the leaf a section (similar in all respects to Plate 5B) shows the same features as those seen in a vascular bundle 12 hours after initial feeding by *E. devastans* but the darkly staining material in the region of the phloem is even more extensive.

The facts elucidated from a study of sections of vascular bundles at varying time intervals after 3 hours of feeding by *E. devastans* show that this insect is primarily a phloem feeder and that the deep staining amorphous substance found plugging phloem cells of vascular bundles fed upon by this insect is either a product of disintegration of phloem cells fed upon by this bug or the result of a reaction between a component of the saliva of the insect and the empty phloem cells.

Sections were next prepared of portions of the leaf on either side of the parts of veins fed upon by *E. devastans*. Plate 6A shows the damage to a small vascular bundle fed upon by *E. devastans* from the upper surface. Here even developing xylem cells are collapsed and plugged. Plate 6B shows a section about 80 microns away from the feeding puncture. It will be noted that the elements of vascular bundle in this region too are collapsed.

The results of the histological studies have therefore shown that the main point of damage by *E. Devastans* in its feeding is the phloem and indirectly the bundle sheath parenchyma. This suggested that the symptoms of damage apparent in a young cacao leaf attacked by the leaf hoppers was the result of interruption of the translocation system which remove metabolites from the leaf. Experiments where leaf hoppers were caged on the midrib about 1 inch below the petiole resulted in the development of typical symptoms of leaf hopper damage on the lamina below the region of feeding on the midrib. The rest of the leaf developed normally.

CHEMICAL ANALYSIS OF CACAO LEAVES ATTACKED BY *E. DEVASTANS*

TENDER and hardening cacao leaves which showed definite signs of attack by *E. devastans* were selected. The leaves in both cases showed extensive attack on the veins, were turning pink in colour

and were relatively brittle. Circular discs 5.6 cm. in diameter were cut out from the leaves while excluding the midrib. Fifteen such discs from either tender or hardening leaves, both attacked by leaf hoppers or normal, were used for a study of moisture, protein and carbohydrate content.

Moisture and dry weight estimations were made by repeated drying of the leaf samples in an oven at 100°C and weighing. Sugars in the leaf samples were estimated as reducing sugars by the Schaffer-Somogyi (1933 and 1937) method. Nitrogen estimations were carried out by the Kjeldhal method and converted into protein (N x 6.25) (Table 2). The water content of tender attacked leaves does not differ widely from that of normal tender leaves. In the case of hardening leaves however the attacked leaves have a lower water content than normal hardening leaves. The protein content of attacked leaves was lowered whereas the sugar content of these leaves was found to have increased over that of normal leaves.

INSECTICIDAL CONTROL OF *E. DEVASTANS* AND *S. DORSALIS*

SMALL-SCALE insecticidal trials were conducted to evaluate the effectiveness of a series of insecticides and methods of application for the control of *E. devastans* infestations. As the thrips *S. dorsalis* was also present in fair populations on the leaf hopper infested cacao plants used in the insecticidal trials, observations were also maintained on the effect of the insecticidal treatments on thrip populations. The leaf hoppers and thrips were almost entirely in the nymphal stages. For each treatment four cacao plants about 10 feet high with heavy infestations of *E. devastans* and *S. dorsalis* were selected. Two young leaves were selected at random from each plant for counting of the populations of these insects. In all cases about 10 leaf hopper nymphs were observed on each leaf examined and the thrip infestation per leaf exceeded 250 to 500.

Treatment of the plants was carried out either by low volume spraying or by high volume spraying or by dusting. In the case of application of insecticides by spraying a knapsack type power driven mistblower was used for low volume spraying and a hand operated knapsack sprayer equipped with a ten-foot lance and dual hollow cone nozzles was used for high volume spraying. Low volume spraying was done at the rate of about 8 to 10 gallons per acre while high volume spraying was done at about 30 to 40 gallons per acre. In all

cases only the younger leaves in each plant was sprayed. As mentioned earlier thrips and leaf hoppers are found almost entirely on the leaves. Dusting was carried out with a knapsack type power duster at the rate of about 10 lb. per acre. In dusting, the entire plants were treated.

Insect population counts were taken before the insecticidal treatments, 24 hours after treatment and again one week after treatment. It will be observed from Table 3 that while all the treatments give satisfactory control of the pests the treatments with DDT, both spraying and dusting resulted not only in good control of but also high residual effectiveness against the two insects.

TABLE 2—Dry Matter, Sugar and Protein Content of Cacao Leaves attacked by E. devastans *and normal Leaves*

Condition of Leaf	*Per cent. Dry Matter*	*Per cent. Nitrogen as Protein in Dry Weight*	*Per cent. reducing Sugars in Dry Weight*
Tender, attacked by *E. Devastans*	18·83	20·08	1·50
	18·39	18·12	0·40
	17·79	18·24	0·60
	17·84	21·50	—
	19·70	16·90	—
Tender, normal	18·13	23·98	0·40
	19·48	24·94	0·40
Hardening, attacked by *E. Devastans*	38·30	15·22	0·50
	23·48	16·19	0·60
	27·10	13·70	0·50
	24·4	16·19	0·40
	25·77	13·71	0·60
Hardening, normal	20·70	21·50	0·20
	21·42	21·40	0·10

TABLE 3—Insecticidal control of **E. devastans** *and* S. dorsalis. *Each figure in the table represents an insect count from a total of two young leaves picked at random from each test plant*

Insecticide and Formulation	*Concentration of Formulation applied*	*Method of Application of Insecticide*	*Infestation of Leaf Hoppers and Thrips 24 hours after treatments*								*Re-infestation 1 week later*
			Tree No. 1		*Tree No. 2*		*Tree No. 3*		*Tree No. 4*		
			L.H.	*T*	*L.H.*	*T*	*L.H.*	*T*	*L.H.*	*T*	
Gamma BHC 20% E. C.	5 fl. oz. in 1 gal. water	Low Volume*	7	—	—	—	—	—	—	—	Present
	2½ fl. oz. in 1 gal. water	Spraying	—	—	—	—	—	—	6	—	Present
	1 fl. oz. in 1 gal. water	High Volume†	—	—	—	—	—	—	—	—	Present
	½ fl. oz. in 1 gal. water	Spraying	—	—	—	—	—	—	—	—	Absent
DDT 25% E. C.	10 fl. in 1 gal. water	Low Volume	—	—	—	—	—	—	—	—	Absent
	5 fl. oz. in 1	Spraying	—	—	—	—	—	—	—	—	Asbent
	2 fl. oz. in 1 gal. water	High Volume	—	—	—	—	—	—	—	—	Absent
	1 fl. oz. in 1 gal. water	Spraying	—	—	—	—	—	—	—	—	Absent
Malathion 57.6% E. C.	16 cc in 1 gal. water	Low Volume	—	—	—	—	—	—	—	—	Present
	8 cc in 1 gal. water	Spraying	—	—	—	—	—	—	—	—	Present
	4 cc in 1 gal. water	High Volume	—	—	—	—	—	—	—	—	Present
	2 cc in 1 gal. water	Spraying	—	—	—	—	—	—	—	—	Present
Diazinon 60% E. C.	8 cc in 1 gal. water	Low Volume	—	—	—	—	2	—	3	—	Present
	4 cc in 1 gal. water	Spraying	7	18	—	—	—	2	4	—	Present
	2 cc in 1 gal. water	High Volume	—	—	—	—	1	—	3	—	Present
	1 cc in 1 gal. water	Spraying	—	—	3	—	3	—	—	—	Present
Gamma BHC 0.65%	10 lb. per acre	Dusting	1	—	3	—	1	—	3	—	Present
Gamma BHC 1.3%	10 lb. per acre	Dusting	1	1 —	2	—	3	—	—	—	Present
Endrin 2% dust	10 lb. per acre	Dusting	2	—	—	—	—	4	—	—	Present
DDT 5% dust	10 lb. per acre	Dusting	—	—	—	—	—	—	—	—	Absent
Dieldrin 1% dust	10 lb. per acre	Dusting	3	—	1	—	5	—	11	—	Present
Untreated Check	—	—	25	+500	20	+500	27	+250	34	+600	Infestation Unchanged

+E. C. = Emulsifiable Concentrate.
* Spraying at about 10 gallons per acre.
† Spraying at about 30 to 40 gallons per acre.
L. H. = Leaf hopper.
T = Thrips.

DISCUSSION

EMPOASCA DEVASTANS has been previously recorded on several plants such as *Hibiscus esculentus, Solanum melongena, Solamum tuberosum, Hibiscus mutabilis, Hibiscus tilliaceus* in India by Afzal and Ghani (1953). In Ceylon it is observed on the same plants and also on beans and cacao. The instance reported in this paper appears to be the first record of *E. devastans* attacking cacao or of leaf malformation, discoloration and premature shedding of cacao flushes following leaf hopper attack.

Experiments where artificial infestations of *E. devastans* have been carried out on cacao have proved that this insect is responsible for malformation, discoloration and premature shedding of cacao flushes. These effects are more rapid in development the younger the cacao leaf and the larger the number of leaf hoppers feeding upon it. Further experiments indicated that no systemic toxin was associated with *E. devastans* feeding as the effects of this feeding were localized to the regions fed upon by the leaf hoppers. These findings are very similar to those reported by Fenton and Hartizell (1928) in their studies on the damage caused by *E. fabae* to potato leaves.

Feeding by caged leaf hoppers on the midrib of cacao flushes usually resulted in a loss of turgor of the leaves followed by all the other symptoms typical of *E. devastans* damage in regions of the leaf below the points of feeding. Observations on leaves attacked by *E. devastans* in the field also showed that the veins were damaged intermittently along their path at many points. Furthermore *E. devastans* was observed to be invariably feeding upon the veins of the leaf on its lower surface. All these observations suggested that the principal site of damage caused by this insect was to the vascular system of the leaf.

Smith and Poos (1931) on the basis of their studies on the histology of the damage caused to leaf tissue by species of the genus *Empoasca* classified these insects into two groups. The first group is characterized by its feeding upon the mesophyll tissue of the leaf and causing the regular production of definite spotting or stippling of the upper leaf surface. In this group the more mature foliage is preferred to the younger more succulent leaves for feeding. *Empoasca maligna, E. obrupta, E. filamenta* and strains of *E. fabae* constitute the second group of feeders mentioned by Smith and Poos (1931). These species evidently feed preferentially upon the phloem or water-conducting tissue and the survival of the species depends upon the availability of fresh phloem in younger succulent leaves.

Histological studies on the damage caused by *E. devastans* to cacao leaf tissue proved that this insect is primarily a phloem feeder. In

the course of its approach to the phloem the parenchymatous bundle sheath is also fed upon. In this respect *E. devastans* is very similar to *E. fabae* in its feeding habits. Smith and Poos (1931) also found that in the feeding by species of the genus *Empoasca* an amber coloured material that stained bright red with safranine was found either in the form of a cylindrical sheath about the punctures made by the insect's mouth parts or in aggregations at the ends of the punctures plugging phloem and xylem. This material was found both in new and in old punctures. Smith and Poos therefore suggested that the presence of the material in the vascular cells might interfere with translocation and thereby cause the symptoms of damage seen in the leaves. Smith (1934) studied the nature of the sheath or plugging material and concluded that it was mainly of insect origin. In the studies conducted on *E. devastans,* reported in the present paper, no marked damage to xylem tubes was observed but phloem tubes and very rarely the feeding tracts were found plugged with a substance which stained heavily with safranine. Sections of cacao leaf fixed at various time intervals after *E. devastans* feeding proved that this plugging material, which was initially almost absent, increased in quantity with time after feeding by the insect. Soon after feeding by *E. devastans* numerous phloem cells are found empty and the walls of these cells stain deeply with safranine. With time the walls of these emptied phloem cells get thicker, collapse and finally appear to coalesce into an amorphous mass which stains very deeply with safranine. These observations precluded the interpretation that the plugging material is purely of insect origin. It would appear more likely in the case of *E. devastans* feeding that this material was predominantly of plant origin produced by an interaction between constituents of insect saliva and phloem cells. Clearly however this plugging material interrupts the translocation system of the leaf.

Biochemical studies conducted by Johnson (1934) on alfalfa leaves damaged by *E. fabae* showed these leaves were higher in dry matter, osmotic pressure of cell sap, reducing sugar, sucrose and starch, total acid hydrolyzable substances and alcohol soluble nitrogen but lower in total nitrogen because of decrease in the insoluble fraction. The chemical analyses reported in the present paper were restricted to work on dry weight, total nitrogen and reducing sugars. The findings in these studies closely parallel those of Johnson (1934) especially where data obtained from hardening leaves are compared. Johnson interprets this over-accumulation of carbohydrate products of photosynthesis as an indication that the translocation system of the leaves has been interrupted by *E. fabae.* The same interpretation is applicable to the findings of *E. devastans* feeding on cacao.

Empoasca devastans appears in large numbers on cacao plants only when young flushes are present and rainfall is absent or sporadic and light. The pest therefore has ideal conditions for heavy population build up in seasons of drought following a brief spell of heavy rain which induces the production of new flushes in cacao plants. Heavy rain during an infestation of *E. devastans* results in almost complete destruction of the nymphs, which stage in reality does the greatest damage to the cacao leaves.

Of the various insecticides tested for the control of *E. devastans,* DDT either as an emulsion spray or as a dust proved both effective and highly residual in its action against the pest. The application of insecticidal treatments with the first appearance of young flushes showing even light infestations of *E. devastans* nymphs will give the best protection of the crop.

SUMMARY

(1) The leaf hopper *Empoasca devastans* and the thrips *Scirtothrips dorsalis* have been studied for their effects on cacao flushes. *Empoasca devastans* definitely is responsible for distortion, stunting of growth, discoloration and premature shedding of cacao flushes.

(2) *Empoasca devastans* feeds upon the vascular bundles of the leaves and if feeding is restricted to a particular area of leaf, damage is similarly restricted suggesting that no systemic toxin is involved in its feeding.

(3) Histological studies of leaves show that *E. devastans* is predominantly a phloem feeder. Mesophyll is never attacked by this insect.

(4) Stylet sheaths have not been observed in feeding tracts of *E. devastans* but a material which stains deeply in safranine and plugs phloem cells can be recognized in leaves attacked by this pest.

(5) The material which plugs phloem cells fed upon by *E. devastans* is mainly of plant origin as it develops with time after feeding and phloem cells seem to disintegrate to form it.

(6) Chemical analyses show that Cacao leaves attacked by *E. devastans* are higher in sugar content and lower in total nitrogen content.

(7) DDT either as sprays or as dust treatments gave the best control and residual effects against infestations of *E. devastans.*

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STUDIES ON THE CONTROL OF PADDY BLAST CAUSED BY PIRICULARIA ORYZAE (BRI ET CAV.)

II. A TECHNIQUE OF SCREENING FUNGICIDES

By G. C. MARKS and J. W. L. PEIRIS

(*Division of Plant Pathology, Department of Agriculture, Ceylon*)

INTRODUCTION

AMONG the current methods used for controlling blast caused by *Piricularia oryzae,* the use of chemicals is one of the most important. Even though the use of resistant varieties offers the best method of control, it is often difficult to incorporate characteristics like resistance to lodging, shattering, suitable age class &c., in the same variety. It is thus likely that we will have to rely on chemical control methods permanently in certain instances as sometimes a variety's susceptibility to blast is outweighed by other desirable characteristics.

The trials were divided into two series of experiments. The first series was confined to development and use of a standardised technique to screen the fungicides, while the second series of experiments was designed to determine the phytotoxicity of the more promising fungicides discovered in Series I.

Abeygunawardena and Peiris (1) using the technique of inhibition of spore germination on glass slides found that Ferric dimethyl dithiocarbamate was very effective even at very low dilutions. They felt, however, that under field conditions such efficacy would not be attainable.

In Japan, mercury formulations are used extensively in blast control work. Peiris (2), however, noticed that some of the *indica* varieties were badly affected by these fungicides. Similar observations have been made in Formosa and China where *indica* varieties are used on an extensive scale.

The following experiments were designed to make a comparative evaluation of the efficacy of the mercurial formulations with the fungicides presently used in blast control work.

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MATERIALS AND METHODS

THE fungicides used in these experiments are listed along with relevant information in Table I. The test plants were grown in upland nurseries, and by altering the spacing, rate of seeding and manurial treatments, they were heavily predisposed to blast. Thus these tests while approximately closely to natural conditions were very rigorous.

The upland nursery beds were sown using the same cultural techniques outlined in an earlier paper (3). One susceptible variety, however, was used in each experiment.

Prior to application of the treatments, the experimental blocks were subdivided into plots, each of which contained 7 rows of plants. At the ends of each block, 5 untreated rows were left to act as buffer strips. Fungicidal drift was avoided by using hard-board shields held within the rows. A fixed volume of about 120 cc of liquid was delivered during each spraying operation using a small hand sprayer which gave a fine, mist-like spray. A hand duster was used for dusting. Care was taken to ensure the dust was blown against the leaves at a fair velocity for it was found that only under these conditions was adhesion on the leaves obtained. All dusting operations were done by a single individual throughout this series to standardise personal error. The dust was applied thinly at a rate which worked out to about 30 lb./acre. After each dusting operation, the leaves were gently flicked with the fingers to remove any excess dust and even out its distribution.

No protection was given to the plants so that the fungicides were exposed to weathering by the elements. However, care was taken to apply the treatments on rainless days so as to enable the fungicides to dry on the leaf. The field conditions under which the fungicides were tested were more severe at Karapincha than at Peradeniya.

METHOD OF ASSESSMENT

USING the standard assessment scale of H. Okamoto, the percentage of leaf area attacked was estimated in each plot. Ten hills, selected at random were chosen for assessment omitting the border rows. The mean of these ten readings expressed the degree of attack in each plot. All assessments were done by a single observer to standardise personal error.

RESULTS

THE composition of the preparations used and their content in the active ingredients are given in Table 1. Symbols have been used instead of trade names. A preliminary screening done at Karapincha

by H. Okamoto (4) showed that FE at dosages of 0.05 per cent. and 0.25 per cent. either with or without a sticker gave about the same degree of control as PX and CT. These fungicides were much inferior to all the mercurial formulations. Of the mercurial compounds ECL and EPL were slightly superior to the wettable phenyl compounds FN and PST. It was noticed, however, that these alkyl dusts and the wettable phenyl compounds were much inferior to the phenyl dusts, yet much superior to FE, PX and CT.

Subsequent tests with the varieties *Mas M 24,* PP2462/12, *Asahi, Podiwi a8,* Siam 29 and *Ptb 16* (Tables IV and V) confirmed these results. From these it was also found that FE Dust and NE were inferior to all the mercury formulations and that the wettable powder Phenyl Mercuric acetate or PMA wettable showed about the same degree of efficiency as FN and PST. FN and PMA Wettable at half the recommended dosage controlled blast only under mild conditions.

In view of the great efficacy of CN Lime lower dilutions were made and screened using the same technique. CN Lime was diluted by weight with talc to give the following dosages of mercury—0.125 per cent., 0.075 per cent. and 0.038 per cent. These diluted Phenyl mercuric dusts were then tested using ECL, FE, FN, PMA Wettable and CX as standards.

From the results obtained (Table VI) it was noticed that CN at all dilutions was very effective both under mild and severe conditions of infection. The efficacy of the Wettable Phenyl compounds deteriorated correspondingly with increase in attack while FE and CX broke down completely. A similar experiment at Karapincha under very severe conditions confirmed these results. (Table (VII)).

EXPERIMENTS ON PHYTOTOXICITY

THERE is a little doubt as to the efficacy of the mercurial formulations in controlling blast. The most effective amongst them, CL and PSL have been reported to be phytotoxic to the *indica* varieties in China Formosa and Ceylon. Consequently a series of tests were done to obtain a comparative evaluation of the susceptibility of *indica* varieties to the toxic action of some of the promising mercurial fungicides.

The seed from the varieties under test were dibbled 6 in. apart in upland nursery beds, sufficient compost and fertilizer being added to ensure healthy growth yet retard the incidence of blast. When the seedlings were about three weeks old, the nurseries were divided lengthwise into strips each of which was treated with a particular fungicide. The results of the treatments were assessed after nine days.

OBSERVATIONS

THE symptoms of phytoxicity appeared about three days after treatment and fullest expression was noticed after about six days. It was possible to divide the symptoms into two categories :—

(*a*) *Lesion Type :* This is the less serious of the two and takes the form of chocolate-brown spots varying in size from a pin point to a rice grain. The margins may be clear-cut or hazy. Sometimes the spots assume an irregular shape, and at times show yellowish halos. Often they closely resemble Helminthosporium or blast lesions. No spots were observed in the newly emerged leaves.

(*b*) *Systemic Type :* This caused severe damage when serious and even when slight often caused a considerable set back to the plant. The treated leaves assumed a scorched, yellow appearance, were often spotted and rapidly became very limp. It is possible that the immediate effect of the fungicide is to cause a disturbance in the water relations of the cells in the affected leaves resulting in loss of turgor. This was followed by rolling of the leaves. The newly-emerged untreated leaves had a pale yellow colour. The growth slowed temporarily so that they appeared stunted when compared to the controls. The results obtained so far have shown that CN and PSL are injurious to many of our varieties. FN is slightly toxic while ECL and EPL are non-toxic.

It has been reported by H. Okamoto (unpublished data) that in the *japonicas* at the heading stage, the varietal susceptibility to toxicity is greater than at the early tillering stage. An experiment was carried out using 36 *indica* varieties to test the correlation between susceptibility to phenyl compounds at early tillering stages on upland nurseries and susceptibility at heading stage under submerged conditions. The varieties varied in the sowing-harvest interval from 6 months to 3 months so that the planting times were staggered accordingly to enable all varieties to commence heading about the same period. CL dust was tested, and the visual assessments were made on both occasions by the same observer. The degree of susceptibility was graded between 0.5 units for the least affected and 5.0 units for the most seriously affected. The results are presented in Table VII. Judging from this Table it can be seen that there is a close correlation between reaction to CL at early tillering and heading stages. The relative damage was, however, about the same.

In all, 136 selections were tested for toxic reactions at early tillering stage ; the results are summarised in Table II.

In these tests FN was applied at twice the recommended dosage, while PMA Dust and PS Dust was applied at about 50 per cent. above normal dusting rates. The Phenyl dusts often produced severe phytotoxic symptoms. The toxic reactions caused by FN were usually mild and sometimes difficult to detect. CN and PSL were often very severe on the plant so that it is not advisable to use them under their existing formulations.

The results of the experiments on fungicidal efficacy and phytotoxicity can be summarised as in Table III.

DISSCUSSION

The techniques used in this series of experiments for the evaluation of fungicides constitute a very rigorous test in comparison with the usual methods employed. Further due to the strong predisposition to the disease its onset was very rapid after primary infection occurred and it was found that the best results were obtained when the first treatments were given at the very onset of primary infection.

It was noticed that under mild epiphytotic conditions, there was very little difference between the degree of control of blast shown by the various mercurial fungicides (Table VI) and as a group they showed much greater efficacy than FE. When conditions became severe, however, the difference between the Phenyl Dusts and Wettable Phenyl Compounds became apparent, while the efficacy of FE deteriorated to a much greater degree. It is likely that the mercurial fungicides are systemic in their action which possibly accounts for their efficacy.

On the basis of these tests, the alkyl dusts Ethyl mercuric chloride with lime and Ethyl mercuric phosphate are the best suited for controlling blast due to their very low phytotoxicity and comparatively greater efficacy than currently recommended formulations. FN and PMA Wettable could be used on a limited scale, preferably on seed farms until their phytotoxicity to Ceylon *indicas* is fully investigated. CL, RL and PSL while showing the greatest efficacy, are too toxic in their present concentrations. However, it has been found that CN at dilutions as low as 0.038 per cent. metallic mercury showed efficacy so that the toxicity of these lower concentrations has to be further determined.

As mercury is highly toxic to human beings the accumulation of mercury in the milled grain has to be investigated. The amounts of residual mercury on straw that has had a history of treatment with mercurial fungicides also needs determination as straw is widely used as fodder.

SUMMARY

A method of evaluating the relative efficacy of fungicides against blast in the field is described and the results of a series of experiments evaluating the efficiency of various formulations of organic mercurials are given.

Of the fungicides tested, Phenyl mercuric acetate and Phenyl mercuric para toluene sulphon anilide dusts were the most effective, while among the liquid formulations Phenyl mercuric dinapthyl methane disulphonate, Phenyl mercuric acetate and Phenyl mercuric paratoluene sulphon anilide were effective. The ethyl compounds, ethyl mercuric chloride dust and ethyl mercuric phosphate dust were superior to the wettable phenyl compounds but inferior to phenyl dusts.

The main types of phytotoxic reactions of mercury formulations are described. The tests on the varietal resistance of paddy to phytotoxicity caused by mercurial fungicides reveal that at the tillering stage, the phenyl dust formulations are toxic to many *indica* varieties. *The japonicas* tested are resistant. The wettable phenyl formulations showed less toxicity while the ethyl compounds were not toxic.

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TABLE 1—Fungicides tested

Symbol	*Fungicide*	*% Active Ingredient*	*Form*	*Dosage used*
CL or RL	Phenyl mercuric acetate with Lime	0.25% Metallic mercury	Dust	About 30 lb/acre
	do.	0.125% Metallic mercury	Dust	do.
	do.	0.075%	Dust	do.
	do.	0.038%	Dust	do.
PSL	Phenyl mercuric para toluene sulphon anilide with Lime	0.25%	Dust	do.
ECL	Ethyl mercuric chloride with Lime	0.25%	Dust	do.
EPL	Ethyl mercuric phosphate with Lime	0.25%	Dust	do.
FN	Phenyl mercuric dinapthyl methane disulphonate	10% (4% Hg)	Wettable powder	1 g/2700 cc
FMA	Phenyl mercuric acetate	1% (0.6% Hg)	do.	1 g/540 cc
PST	Phenyl mercuric para toluene sulphon anilide	1 tab. (90 mg Hg)	Tablet (water soluble)	1 tab./600 cc
PN	Cuprous Oxide	50%	Wettable powder	1 g/400 cc
CT	Copper oxychloride	50%	do.	1 g/400 cc
FE	Ferric dimethyl dithio carbamate	76%	do.	1 g/400 cc
FE	Ferric dimethyl dithio carbamate	8%	Dust	30 lb/acre
NE	Ferric dimethyl dithio carbamate Ferric benzothyacyl mercaptide Manganous dimethyl dithiocarbamate Manganous benzothyazyl mercaptide Tetra methyl thiuramdisulphide	3.12% 0.28% 2.68% 0.11% —	Dust	30 lb/acre
CX	Dodecyl gunadine acetate	70%	Wettable powder	1 g/340 cc 1 g/680 cc

TABLE II—Phytotoxicity of mercurials to rice varities

Variety	*No. Tested*	*Percentage of plants effected by*									
		CL		PSL		FN		ECL		EPL	
		Lesion type	*Systemic type*	*Lesion type*	*Systemic type*	*Lesion type*	*Systemic type*	*Lesion type*	*Systemic type*	*Lesion type*	*Systemic type*
1. Departmental Pure lines, Indica & Indonesian	58	34·5	34·5	32·5	32·5	17·3	4·3	0	0	0	0
2. Local Indica Selections	51	68·6	72·5	58·8	45·0	—	—	—	—	—	—
3. Japonica Varieties*	37	16·2	0	8·1	0	0	0	0	0	0	0

* *May possibly include a few indica varieties from Formosa and China.*

TABLE III—Relative efficacy of fungicides

Fungicide	*Conc.*	*Dosage* rate	*Relative Efficacy (Control=100)*	*Toxicity to indica varieties*
1. C L	0.25%Hg	00 lb.	2000	Severe
2. R L		acre		
3. P S L	0.25%	do.	1900	High
4. E C L	0.25%	do.	1000	Non toxic
5. E P L	0.25%	do.	1000	Non toxic
6. F N	1 g/2700 cc	120 gls/acre	800	Slight
7. PMA Liquid	1 g/500 cc	do.	750	Slight
8. PST	1 Tablet 6000 cc	do.	750	—
9. P N	1 g/400 cc	do-	200	—
10. F E	8% Active Ingredient	30 lb/acre	300	—
11. F E Liquid	1 g/400 cc	—	200	—
12. N E	—	30 lb/acre	200	—
13. C X	1 g/400 cc	120 gls/acre	110	—
14. Control	—	—	100	—

TABLE IV—Relative efficacy of fungicides

Fungicide	*Active Ingredient*	*Dosage*	*Form*	*% Leaf destruction*		
				Mas	PP2462/11	*Asahi*
1. CL	0·25Hg	30 lb./acre	Dust	8·55	0·45	0·20
2. RL	0·25%	do.	Dust	0·55	0·45	0·20
3. PSL	0·25%	do.	Dust	0·30	2·2	0·20
4. ECL	0·25%	do.	Dust	25·7	5·12	6·15
5. EPL	0·25%	do.	Dust	7·8	3·15	2·15
6. FN	10%	1 g/2700 cc	Liquid	9.15	3·10	0·40
7. FN	10%	1 g/5400 cc	do.	—	—	—
8. PST	90 mg/tab.	1 tablet 6000 cc	do.	11·7	1·50	0·55
9. PX	50%	1 g/400 cc	do.	2·91	6·70	19·7
10. CT	50%	do.	do.	31·4	12·5	9·7
11. FE	76%	do.	do.	37·5	10·7	20·7
12. Control	—	—	—	57·0	21·6	28·2

TABLE V—Relative efficacy of fungicides

Fungicide	*Ingredient*	*Dosage*	*Type*	*%Leaf Destruction*		
				Podiwia 8	P/P.*16*	*Siam 29*
CL	0·25%	30 lb./acre	Dust	2·3	1·1	0·35
ECL	0·25%	do.	do.	18·0	2·8	2·7
EPL	0·25%	do.	do.	23·5	3·0	2·5
FN_1	10%	1 g/2700 cc	Liquid	26·9	9·0	4·6
FN_2	10%	1 g/5400 cc	do.	51·2	18·0	7·2
PMA Wet_1	1·0%	1 g/500 cc	do.	20·5	12·0	5·4
PMA Wet_2	1·0%	1 g/1000 cc	do.	55·5	7·4	4·8
PST	90 mg/tab	1 tablet 6000 cc	do.	36·0	8·0	6·7
PE	76%	1 g/400 cc	do.	82·0	38·0	27·0
PX	50%	do.	do.	76·0	17·0	12·0
NE	—	30 lb./acre	Dust	71·0	36·0	25·5
Control				100	38·0	47·5

TABLE VI—Relative efficacy of fungicides

Fungicide	*Ingredient*	*Dosage*	*Type*	*% Leaf Destruction*		
				Peradeniya		*Karapincha*
				16·11.58	*22·11.58*	*23·10.58*
CL	0·25%Hg	30 lb. /acre	Dust	0·1	3·4	30·0
CL	0·125%	do.	do.	0·2	1·7	26·6
CL	0·075%	do.	do.	0·1	1·6	31·5
CL	0·038%	do.	do.	0·3	5·8	28·3
ECL	0·25%	do.	do.	1·5	4·7	31·5
PMA Wet	1·5%	1 g/500 cc	Liquid	0·2	9·8	61·0
FN	10%	1 g/2700 cc	do.	0·2	12·7	53·3
CX_1	70%	1 g/340 cc	do.	26·5	60·0	—
CX_2	70%	1 g/680 cc	do.	25·0	66·0	—
PE	76%	1 g/400 cc	do.	20·0	60·0	91·3
Control				41·0	77·0	96·6

TABLE VII—Varietal Susceptibility to damage by mercurial fungicides

Variety	At 4 week stage		At Heading		Degree of* Susceptibility
	Sys.	Les.	Systemic type	Lesion type	
HMC 12 ..	0	0	0	1·5	MS
Dahanala 2014 ..	2	0	0	0	RR
H 102 ..	—	—	5·0	0	SS
H 5 ..	0	0	0	1·0	MS
H 103 ..	3	2	1·0	1·0	MS
H 501 ..	5	3	5·0	0	SS
H 2 ..	5	3	0	5	SS
H 105 ..	4	0	3	0	SS
Hondarawala 502 ..	0	0	1	1	MS
Heenati 309 ..	1	0	3	0	SS
Heenati ICPY 15 ..	0	4	0	0·5	R
Kurulutuduwi ..	0	0	0	0·5	R
M 303 ..	0	0	0	1	MS
M 304 ..	0	0	0	1	MS
M 302 ..	5	1	2·5	0·5	SS
M 3 ..	4	0	3	0	SS
Madael 137 ..	3·5	0	0	3	SS
Murunga 307 ..	5	0	3	0	RR
Murunga 137 ..	5	0	5	0	SS
Murunga 308 ..	5	5	2	2	SS
Ptb 16 ..	0	0	0	2	SS
Perillanel 26014 ..	4	3	5	1	SS
Pokkali ..	0	0	0	1	MS
PP 2462/11 ..	0	0	0	0·5	R
Siam 29 ..	0	1	0	2	MS
Sulai 27614 ..	5	0	2	1	MS
Sulai 301 ..	5	1	5	0	SS
Suduheenati Hf9 ..	5	1	5	0	SS
Sinnanayan 2208 ..	0	0	0	0	RR
Sinnanayan 398 ..	0	0	0	0	RR
Suduwee 305 ..	0	0	0	0	RR
Uvar Vellai ..	5	3	4	0	SS
Vellai perunel ..	0	0	0	0	RR
Devaredderi ..	0	0	0	2	RR

* RR Very resistant
R Resistant
MS Moderately resistant
SS Very susceptible

METEOROLOGICAL REPORT

Summary for April to June, 1959

Afternoon and evening thunderstorms were fairly widespread practically throughout April. The greater monthly totals of rainfall (20 to 30 inches) were recorded mainly along the southwestern and southeastern slopes of the hills while least rainfall (totals below 2 inches) was experienced chiefly in the extreme north and northeast. Rainfall over the Island was mostly above nomal, the larger excesses (10 to 12 inches) being experienced among the hills and in the western low-country areas. The bigger deficits (5 to 10 inches) were recorded in the southwest.

Inter-monsoon thunderstorms continued during the first 10 days of May giving fairly widespread, but scattered, rain over the Island. Weather became unsettled on the 11th and the unsettled conditions persisted for 2 or 3 days causing thundery showers over most parts of the country. This was followed by another spell of afternoon and evening thundershowers until the south-west monsoon set in about the 17th of the month. The rest of the month was marked by monsoon showers in the southwest quarter and among the hills and occasional scattered thundery showers in the north and east. The greater monthly totals of rainfall (20 to 30 inches) were recorded in the southwest quarter while least rainfall (totals below 2 inches) were experienced in the east. Rainfall was mostly below normal in the southwest and above normal elsewhere.

The main feature of the weather during June was a depression in South-West Bay of Bengal which resulted in strong winds and heavy rain practically throughout the Island between the 17th and 21st. Due to these rains the Kelani Ganga was above the minor flood level on the 24th and 25th. On account of the associated unsettled weather conditions fairly widespread thundery showers were experienced from the 12th to 22nd. During the rest of the month active monsoon weather prevailed, the rainfall being mainly confined to the south-west quarter and the central hills. Rainfall was highest along the south-western slopes of the central hills where the totals generally exceeded 30 inches. In the south-western coastal area rainfall totals were of the order of 10 inches. Outside the southwest quarter rainfall decreased rapidly, the monthly totals being mostly below 2 inches. The rainfall was above normal except along the south-eastern slopes of the central hills and in the Colombo-Wariyapola-Puttalam Triangle.

A. P. KANDASAMY,
Director.

Department of Meteorology,
Bullers Road, Colombo 7, August 25, 1959.

	APRIL								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps)	Total	Offset	No. of days
Anuradhapura ..	92·3	+0·6	74·4	0	74	95	12·13	+5·70	20
Badulla ..	85·5	+1·3	66·5	+0·3	76	95	12·63	+5·63	21
Batticaloa ..	88·2	+0·3	77.1	+0·4	77	91	7·57	+5·27·	12
Colombo ..	88·3	+0·5	75·9	+0·1	72	93	18·37	+9·30	18
Diyatalawa ..	79·2	+1·2	61·2	+0·6	78	94	10·11	+3·57	20
Galle	86·3	+0·2	76·9	+0·2	74	82	13·72	+5·01	18
Hambantota ..	88·3	+0·7	77·3	+1·0	74	89	2·53	—1·33	10
Jaffna	90·2	+0·6	80·8	+0·6	74	85	4·31	+2·08	9
Kandy	87·9	+0·2	70·1	+0·2	72	95	16·37	+10·37	16
Kankesanturai ..	92·0	+0·5	79·1	+0·5	69	89	2·69	+1·15	5
Kurunegala ..	92·0	+1·1	74·9	+0·3	70	93	17·01	+7·10	17
M' Illuppallama ..	92·0	+0·7	74·0	+0·1	69	90	6·80	—0·44	14
Mannar ..	91·3	+0·9	78·8	+0·8	72	84	6·08	+2·66	12
Nuwara Eliya ..	72·7	+1·5	50·8	+0·9	76	87	8·00	+3·02	16
Puttalam ..	90·4	+1·1	76·5	+0·4	70	86	10·17	+5·29	13
Ratmalana ..	89·4	+1·4	75·8	+0·2	74	93	12·27	+1·70	20
Ratnapura ..	91·3	+0·1	73·8	+0·1	76	95	18·11	+6·54	21
Talawakele ..	75·7	—1·8	68·0	+0·2	78	88	7·62	+1·32	17
Trincomalee ..	91·3	+2·0	77·9	+0·2	69	84	2·64	+0·51	10

	MAY								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps)	Total	Offset	No. of days
Anuradhapura ..	90·1	—0·8	75·6	—0·8	78	95	8·23	+4·69	15
Badulla ..	85·8	+0·2	67·1	+0·7	73	95	2·99	—1·70	16
Batticaloa ..	90·6	+0·2	78·4	+0·6	72	89	1·07	—0·72	7
Colombo ..	87·2	+0·3	76·8	—0·9	78	91	12·05	—3·44	25
Diyatalawa ..	78·9	+0·1	62·9	+0·9	76	89	5·69	—0·37	17
Galle	85·7	+0·8	77·4	—0·7	78	86	12·86	+0·19	23
Hambantota ..	87·0	+0·2	77·7	+0·1	78	89	4·50	+0·23	14
Jaffna	89·4	+1·3	82·3	+0·6	76	83	2·12	+0·12	6
Kandy	85·6	—0·3	70·9	+0·3	74	92	1·84	—4·67	15
Kankesanturai ..	91·9	+0·1	80·9	—0·5	70	87	1·53	—0·04	5
Kurunegala ..	89·9	+0·8	75·6	—0·5	76	93	10·90	+3·35	21
M' Illuppallama ..	90·0	—0·8	74·8	—1·6	74	90	7·68	+3·50	14
Mannar ..	89·9	+0·4	80·8	0	74	82	6·20	+4·41	14
Nuwara Eliya ..	72·6	+2·3	54·8	+1·4	76	85	5·71	—2·76	22
Puttalam ..	89·6	+1·2	78·1	—0·8	72	84	9·64	+5·87	23
Ratmalana ..	88·5	+1·2	77·5	—0·5	76	91	11·58	—4·83	24
Ratnapura ..	90·3	+1·3	74·5	—0·4	78	95	15·93	—4·98	27
Talawakele ..	75·7	+0·2	59·3	—0·4	53	91	10·38	+0·97	22
Trincomalee ..	93·0	+0·6	79·6	+0·8	64	80	2·69	—0·54	10

	JUNE								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps)	Total	Offset	No. of days
Anuradhapura ..	87·7	—2·3	76·1	—0·3	75	91	2·74	+2·01	7
Badulla ..	84·1	—1·3	66·9	+1·5	68	89	0·60	—0·94	8
Batticaloa ..	92·1	—0·2	76·5	—1·2	67	86	1·75	+0·86	7
Colombo ..	84·6	—0·7	77·2	—0·1	82	86	12·31	+3·85	24
Diyatalawa ..	76·5	—1·1	63·7	+0·5	70	82	4·37	+2·41	9
Galle	82·8	—0·7	76·4	—0·8	83	86	18·40	+9·96	27
Hambantota ..	84·2	—2·1	77·4	+0·6	82	86	4·64	+2·53	13
Jaffna ..	86·5	—0·2	81·3	+0·4	80	85	5·36	+4·97	7
Kandy ..	80·5	—1·6	71·1	—2·0	72	88	9·52	+2·22	24
Kankesanturai ..	90·0	—1·0	80·8	+0·2	74	85	0·41	—0·16	4
Kurunegala ..	85·2	—1·3	75·8	+0·2	80	91	11·55	+4·76	23
M' Illuppallama ..	87·6	—2·5	75·3	—0·8	74	88	1·44	+0·11	11
Mannar ..	87·9	—0·3	80·8	+0·2	76	80	2·24	+1·88	6
Nuwara Eliya ..	65·3	—0·3	57·0	+1·3	82	83	18·28	+7·85	27
Puttalam ..	87·1	0·6	79·4	+0·2	72	80	1·09	—0·31	10
Ratmalana ..	85·2	—0·2	77·4	0	82	89	15·45	+6·47	25
Ratnapura ..	84·9	—1·8	74·2	—0·5	82	93	26·37	+7·82	28
Talawakele ..	69·7	—1·0	61·1	+0·7	87	91	20·25	+6·97	27
Trincomalee ..	91·5	—0·8	78·8	—0·3	64	78	3·86	+2·93	10

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